"I WOULD SAY THAT MIGHT BE ALL IT IS, IS HOPE": DISRUPTION, ATTACHMENT, AND FARMERS' FRAMING OF HERBICIDE RESISTANT WEEDS

By

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ABSTRACT

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While herbicide resistance has been an agricultural issue for decades, it is currently getting growing attention from academics, chemical companies, extension educators, and farmers. This is largely the result of weeds' increasing resistance to the popular herbicide glyphosate. Although an Integrated Weed Management approach is recommended to combat herbicide resistance, farmers are hesitant to adopt it and instead continue to express faith in herbicide solutions. Recognizing that society and nature are inseparable causes of this phenomenon, I introduce a sociological perspective to a field dominated by 'hard sciences' in order to clarify why farmers maintain faith in and use of herbicides in the face of increasing herbicide resistance and suggested alternative integrated management practices. In order to do this, I employ a three chapter format. My first chapter focuses on how farmers draw on master frames to understand and make meaning of their reliance on herbicides. This uncovers issues of farmers' false trust in herbicides due to structurally binding conditions. My second chapter draws from place literature to understand herbicide resistant weeds as disruptions of place, arguing that these weeds present an observable challenge to farmers' herbicide dependence that threatens and therefore triggers farmers' place attachment. Together, these chapters describe how farmers understand herbicide resistance and their own reactions to it based on socio-environmental stimuli. Finally, my third chapter focuses on how quality data about farmers can be collected. Drawing from mixed methods, I suggest a framework of relational pragmatism that can be used to more effectively achieve this goal.

Dedicated to my Ba. I love you too much.

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To my parents – you always believed I could do it, so I did. To my Uncle Dick – you taught me that nerdy is cool. And to Sam – your love keeps me moving.

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Herbicide resistance – the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicides that is normally lethal – has presented a management issue for farmers ever since common groundsel (*Senecio vulgaris*) was confirmed resistant to atrazine in the state of Washington in 1970 (Ganie and Zahoor 2017). Although this resistance did not prove to be especially problematic, it was a sign of what was to come. In 1979, widespread resistance to atrazine in common lambsquarters (*Chenopodium album)* was first recognized, resulting in significant increases in management cost and promotion of Integrated Weed Management practices (Bosak 2015). The newest iteration of this problem, in the form of glyphosate resistance, presents a major challenge for farmers due to its dominance of use. Glyphosate was introduced as a commercial herbicide in 1974 by Monsanto under the name 'RoundUp' and followed by the release of glyphosate tolerant 'RoundUp Ready' corn varieties in 1996 and soybean varieties in 1997(Barman et al. 2014; Ganie and Zahoor 2017; Livingston et al. 2015). By 2001, one year after its patent with Monsanto expired, glyphosate under different brand names became the most widely used herbicide in the US (Livingston et al. 2015). Given this widespread adoption, glyphosate provides a key case study of how synthetic inputs are used, and their consequences dealt with, in US agriculture today.

As patented under RoundUp, glyphosate's effectiveness induced farmers to adopt it versus other competitive products. Part of this adoption had to do with farmers' historically positive experiences with glyphosate as a spot herbicide. Once vertical integration with seeds occurred, farmers were quick to adopt glyphosate on a farm-wide basis. Glyphosate's success was also boosted by its ability to kill any grass or broadleaf plant, relative ease of use, low health risks, and comparatively low environmental impact (Bullock and Nitsi 2001; Hammond, Luschei, Boerboom and Nowak 2006; Gusta, Smyth, Belcher, Phillips and Castle 2011; Livingston et al. 2015) making it particularly appealing in an increasingly large-scale US farming system. Additionally, glyphosate was heavily promoted by Monsanto, who all but guaranteed that it was not possible for weeds to develop resistance to glyphosate (Bonny 2016).

Due to this promotion and farmers' perceptions of the benefits of glyphosate, it quickly became the predominant weed management tool for US farmers (Livingston et al. 2015). As of 2015, glyphosate was applied to glyphosate-tolerant crop varieties to control weeds on 93 percent of soybean acres and 85 percent of corn acres in the US (Livingston et al. 2015). This makes weed resistance to glyphosate of particular concern. The introduction of glyphosate, along with glyphosate resistant crops, allowed farmers to manage weeds easily in a one-pass operation, which coupled with larger equipment, allowed farmers to expand acreage and still make timely herbicide applications. Thus glyphosate helped to enable this growth in farm sizes through significant reductions in management time and complexity; however it also may be creating a situation of dependency wherein large farms cannot operate without relying on a simplified, glyphosate-based weed management program (Egan 2014; MacDonald 2011).

The continuous use of glyphosate, despite Monsanto's original claims, did result in the development of herbicide resistant weeds. This began in the US when rigid ryegrass (*Lolium rigidum*) was first confirmed to be glyphosate resistant in 1996 in California (Heap 2016); the same year that glyphosate-tolerant crop varieties were introduced commercially. However, rigid ryegrass is certainly not the most rapidly developing or widespread glyphosate resistant weed. As of 2016, the population of herbicide resistant weeds in the US has grown to represent 155 weed species, with at least 16 of those species having confirmed cases of resistance to glyphosate. This makes the US the world leader in number of glyphosate resistant weed species just ahead of Australia (Heap 2016). Although US farmers have long dealt with weed resistance to different herbicides, glyphosate resistance presents an unprecedented conundrum in terms of its detrimental impact on farm profits, wide range, and lack of forthcoming herbicides to replace it (Livingston et al. 2015). Furthermore, new herbicides and combinations of herbicides have the potential to create multiple resistances in weeds. For example, many Palmer amaranth (*Amaranthus Palmeri*) populations are now resistant to glyphosate, ALS, PPO inhibitors, and triazines, forcing farmers to find ever newer herbicide options or fall back on non-chemical management (Mortenson et al. 2012). Thus the evolution of weed resistance – and glyphosate resistance in particular – is emblematic of growing concerns with large acreage farms that implement management decisions based on an economy of scale. (e.g. Binimelis et al. 2009; Egan 2014).

Weed resistance – like other unintended consequences of conventional agriculture – needs to be managed for the economic, social, and environmental sustainability of farming. This is particularly pertinent given that herbicide resistant weeds have resulted in significantly higher weed management costs, lower crop yields, increased environmentally harmful practices such as tillage and the application of more volatile herbicides to manage these weeds (Bonny 2016; Culpepper, Owen, Price and Wilson 2012; Inman 2016; Livingston et al. 2015). One of the most widespread and damaging glyphosate resistant weeds in the US, Palmer Amaranth density in cotton increased by a factor of 9 over a 4- year period when glyphosate was the only method of weed control (Inman 2016). Such weed densities result in serious competition with crops and necessitate costly measures such as hand-pulling weeds (Culpepper, Owen, Price and Wilson 2012; Inman 2016; Neuman and Pollack 2010), which increase farm management costs significantly. The presence of herbicide resistant Palmer Amaranth on cotton farms in the state of Georgia increased management costs by up to 58 percent (Webster and Sosnoskie 2010).

Experts suggest that the best way to manage weed resistance and avoid associated consequences is through Integrated Weed Management (IWM), which combines physical, cultural, mechanical, and chemical weed management practices (Barman et al. 2014; Egan 2014; Harker 2013). For example, cultural practices may include crop rotations, row spacing, planting date, cover crops, and scouting. These may be used in tandem with physical management (i.e. hand pulling or hoeing), mechanical controls such as cultivation, and chemical management utilizing multiple herbicides – all of which is dependent on crop type, land type, soil type, etc. In this way, chemical weed management becomes one facet of a larger weed management program, preventing the large-scale resistance problems that occurred with glyphosate and preserving the effectiveness of herbicidal control options (Egan 2014; Harker 2013). Similar integrated approaches exist for pest management, retention of soil quality, and other sustainable remedies for the consequences of conventional agriculture (Gould 1995; Hammond et al. 2006; Vanlauwe, Bationo, Chianu, Giller, Merckx, Mokwunye, Ohiokpehai et al. 2010).

However, despite education on weed resistance and best management practices, farmers have been slow to adopt IWM particularly if they do not yet have herbicide resistant weeds on their own farms (Llewellyn, Lindner, Pannell and Powles 2004; Webster and Sosnoskie 2010). While this may be due in part to cost, lack of knowledge, and high labor requirements, it also appears that ideological trends in Western society influence how farmers frame various issues, including herbicide resistance, in turn impacting their management approaches (Llewellyn et al. 2004; Mooney and Hunt 1996; Webster and Sosnoskie 2010). Indeed, farmers have been shown to maintain a strong faith in herbicides and the development of new herbicide modes of action despite the fact that no new herbicides have been discovered in two decades (Boerboom and Owen 2006; Bonny 2016; Livingston et al. 2015; Llewellyn et al. 2004; Norsworthy et al. 2012; Webster and Sosnoskie 2010).

In research on the herbicide resistance issue, the so-called 'social' aspects have been largely ignored while the focus is instead on 'natural' aspects such as weed biology that are considered 'outside' of society. Indeed, research on the social dimension of agricultural issues have been ignored, resulting in a preponderance of emerging social/ecological/environmental problems related to our agricultural system. This separation of 'nature' from 'society' paints an incomplete picture of agricultural problems such as herbicide resistance, which are in actuality part of an inseparable conjoint constitution (Freudenburg, Frickel and Gramling 1995) of 'natural' and 'societal' issues. It is impossible to address herbicide resistance without taking a conjoined perspective on nature and society, emphasizing the need to incorporate sociology into all aspects of agricultural research. In recognition of this, there is a call for integration of social sciences disciplines into weed management studies (i.e. Ervin and Jussaume 2014). Yet, when social aspects *are* studied, it is often in terms of economics or adoption education considered separately from the 'natural world'. Therefore, when education is shown to have little influence on farmers' adoption of best weed management practices (Carolan and Stuart 2015), the *why* hangs unanswered or at best considered separate from 'nature'.

Sociology as a discipline could contribute much to the understanding of weed management and other problems associated with agriculture production in the US by considering society and agriculture in conjoint constitution with the environment and related sustainability (Dunlap and Martin 1983; Foster 2002). In my dissertation, I will contribute to this research directive as I delve into issues of framing, attachment, and what drives farmers' attitudes and practices related to weed management on their farm – particularly their lack of adoption of IWM methods and continued reliance on herbicides for weed management. Glyphosate resistance is emblematic of herbicide resistance which in turn acts as an 'indicator case,' reflecting a larger ideology in US agriculture that focuses on technological, often chemical, solutions to various problems and eschews community-based approaches. The framing and attachment of farmers are in turn impacted by biophysical place characteristics and the structure of conventional agriculture in the US, iteratively influencing the options available to farmers – i.e. their agency of choice. Although IWM is promoted and education programs are offered, growers do not necessarily choose to adopt best management practices (BMPs) *despite understanding their benefits* (Binimelis et al.2009; Carolan and Stuart 2015; Johnson et al. 2009). This points to the larger applicability of my dissertation in understanding how the conjoint constitution of social and natural variables lead to interpretations that produce conflicting prognoses and decision-making.

My overarching research goal for my dissertation is to investigate how US farmers conceptualize and manage herbicide resistance as an example of how sociology can contribute to an improved understanding of the social, cultural and environmental dimensions of US and global agriculture. In addition, I want to show how these issues might be more effectively studied. In order to achieve this goal, I break my dissertation into three chapters, each with specific objectives that will aid in addressing my larger research goal. Chapter 1 addresses how farmers' cognitive framing of herbicide resistance interacts with a larger agricultural sociotechnical imaginary to impact weed management behaviors, helping to bridge cognitive and cultural reasons for different types of management. Chapter 2 introduces a spatial understanding to the issue, investigating how herbicide resistant weeds act upon the farmers' whose fields they infest. These two chapters act to cover structural, agential, and spatial components of farmers' herbicide resistance management, drawing a more complete picture of the conjoint constitution underlying weed management and other problems of conventional US agriculture. My final chapter acts as a guide to future researchers interested in this topic. Structural, agential, and spatial components are important but not the only predictors of herbicide resistance management. If we are to understand the problem, further research needs to be conducted. Chapter 3 addresses methodological issues associated with researching farmers and suggests a theoretical grounding for mixed methods that can be used to expand this and other fields of study. Below, I briefly review each of these chapters in turn, followed by a discussion of methodology and a summary of my research goals.

CHAPTER 1

My first chapter addresses how farmers explain their continued use of chemical-dependent weed management programs through cognitive framing and cultural repertoires. To reach this goal, I draw on sociotechnical imaginaries and master frames. Sociotechnical imaginaries are defined by Jasanoff and Kim (2009) as "collectively managed forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (p. 120). They reflect attainable, prescribed, and desired futures by promoting collective visions of 'good society' that are achievable through certain technologies. Within US agriculture, I describe a sociotechnical imaginary in which the envisioned 'good' agricultural society is essentially productivist and achieves this through the application of technologies and economies of scale. This sociotechnical imaginary is, I argue, both producing and reinforcing a master frame that farmers can draw upon to make meaning of their herbicide resistant weed management actions.

Master frames themselves are culturally resonant, general, symbolic repertoires of interpretation that can be drawn upon by a variety of actors to identify problems, specify grievances, and justify goals (Benford 2013; Berbrier 1998; Gerhards and Rucht 1992; Swart 1995). They have the potential to interact with sociotechnical imaginaries in that master frames can be drawn upon to justify the goals and strategies suggested by such imaginaries. Additionally, the resonance of master frames may be increased by ascription to a certain sociotechnical imaginary, resulting in an iterative support cycle. This interaction of sociotechnical imaginaries and master frames will aid in understanding the processes of trust and meaning making that farmers are going through when they a) express hope or faith in new herbicide development and b) continue to rely on only herbicides despite knowing better. Given that master frames can be drawn upon to explain a whole suite of attitudes and actions, I expect that my focus on herbicide technology has wider applicability to US farmers' use and rationalization of many conventional agricultural technologies.

Applied to the problem of herbicide resistance, I ask what master frames US corn and soybean farmers are drawing on to explain their trust in herbicides and continued use of these herbicides. I anticipate that these master frames will have resonance with the sociotechnical imaginary of US agriculture and that farmers will apply frame amplification to make their master frame align with productivist and technological goals. This leads me to 3 primary research questions for this chapter; *Question 1)* What master frame(s) do farmers draw on to make meaning of their weed management practices?, *Question 2)* How do these master frames interact with the US agriculture sociotechnical imaginary?, and *Question 3)* Is herbicide resistance presenting a challenge to the dominant master frame dictating how weed management should be done? To address these questions I employ eclectic coding and code mapping of farmer focus groups.

CHAPTER 2

Some preliminary findings from the focus groups conducted for this dissertation suggest that place (including community and biophysical elements) has an influence on attitudes towards and use of integrated weed management strategies. In particular, it appears that regions and individual farms experiencing greater physical density or threat of herbicide resistant weeds lead farmers to be significantly more concerned about herbicide resistance and more likely to be losing faith in chemical management options. This trend is supported by Bonny (2016) who found that farmers whose farms were already infested with herbicide resistant weeds were more likely to use IWM strategies than those without weed resistance. I propose to further explore this place-based difference in management through an investigation based on the place attachment literature and Structural Equation Modeling (SEM). Specifically, I posit that herbicide resistant weeds act as a place disruption triggering increased place attachment in farmers, which may result in either more or less integrated weed management. This can then be extrapolated to consider other types of place disruption driven by current agriculture practices.

Although place attachment has been shown to impact farmers' management practices (Lincoln and Ardoin 2015; Marshall, Park, Adger, Brown and Howards 2012), which place attachment dimensions are relevant determinants of people's behavior are confusing and of contested importance. For instance, biophysical drivers of place attachment have only recently been included in larger conceptualizations of place attachment dimensions (Lewicka 2011; Stedman 2003), and have been shown to have disparate impacts on peoples' environmentally friendly behaviors. This is particularly relevant to place disruptions – a disruption to the physical environment can have a significant impact on place attachment and associated place-protective behaviors, but has been understudied in comparison to migration or mobility-based place disruptions (Manzo and Devine-Wright 2014). A disruption framework may have specific relevance to the study of herbicide resistant weeds – these weeds likely constitute a disruption, or perceived threat, to farmers' property and quality of life. Such weeds may then act to trigger latent place attachment attitudes in farmers that promote different kinds of management responses (Manzo and Devine-Wright 2014).

In order to investigate the kinds of place attachment relevant to farmers, as well as whether herbicide resistant weeds constitute a place disruptive factor that can impact farmer behavior, I draw on several definitions in the literature. First, I use factor analysis to test the relevance of various place attachment dimensions suggested by Stokols and Shumaker (1981), Proshansky (1978) Raymond, Brown and Weber (2010), Ardoin, Schuh and Gould (2012) and Scannell and Gifford (2010). Secondly, I test the place disruption framework proposed by Mihaylov and Perkins (2014) in which place disruptions are posited to interact with community factors to influence individual's interpretation of the disruption. This interpretation then guides whether action against the disruption is taken. Based on these goals, I ask four primary research questions; *Question 1*) Can farmers' place attachment can be broken into biophysical, community, identity, dependence, and family dimensions? *Question 2*) How does the presence of place-disruptive herbicide resistant weeds impact farmers' place attachment?, *Question 3*) Do dimensions of farmers' place attachment impact their interpretation and management of herbicide resistant weeds?, and *Question 4*) How will the disruption model of place attachment perform in relation to herbicide resistance management?

CHAPTER 3

Researching farmers in the US is of the utmost importance to promote environmental, social, and economic sustainability. However, such research has become increasingly difficult – especially given plummeting survey response rates among farmers (Pennings, Irwin and Good 2002) and methodological monism in rural sociology (Harper 1991). This is true not only of the US farming population – many groups in the US have become 'over-surveyed' with resulting low response rates (Groves 2011). The purpose of this paper is to explore the utility of an exploratory mixed methods design for researching farmers in the US, particularly applied to socio-environmental dimensions of farmers' herbicide resistant weed management. This is intended as a case study exploring how a mixed methods approach can help researchers collect better data on a variety of populations, addressing the shortcomings of quantitative and qualitative methods to collect higher quality information from respondents. Additionally, I will develop a theoretical framework guiding the *creation* and *implementation* of mixed methods – expanding on the more common development of theory related to the *justification* of mixed methods as a methodology (e.g. Ahram 2011; Burke Johnson and Onwuegbuzie 2004; Denzin 2010; Giddings 2006; Greene 2008). I envision that this theoretical framework will have practical implications for research both in sociology and other disciplines.

Combining the perspectives of pragmatism and relationalism, I advocate for a relational pragmatic approach to conducting mixed methods research. This approach is founded on building new relationships and drawing on existing relationships with local charismatic, important, and expert persons – as well as building relationships with the individuals that are being studied. These relationships help define the realistic, that is pragmatic, ways to choose and implement a mixed methods study.

Given the practical and theoretical concerns with mixed methods, I see a need for research designs that both test the utility of mixed methods and aid in the development of a theoretical grounding for mixed methods. In this paper, I advance such a case study in which I use an exploratory mixed methods design to research socio-environmental dimensions of farmers' attitudes towards herbicide resistant weeds. This case study helps to answer the research question 'Are mixed methods, as conceptualized under relational pragmatism, an effective alternative to mono-methods (such as a single survey or set of focus groups) for researching the US farming population?' Therefore I will not only be testing the usefulness of a mixed methods design applied to a farming population, but drawing on my experience using mixed methods to develop and advance a theoretical grounding in relational pragmatism.

METHODS

In order to answer the above research questions for all three of my chapters, I use focus groups and a survey in an exploratory mixed methods design. This is particularly useful given the poorly understood socio-environmental dimensions of herbicide resistance – exploratory mixed methods are most appropriate when the research question is relatively complex and/or has little existing literature and data collection tools (i.e. pre-existing measurement scales) (Creswell and Plano Clark 2011). I have chosen to use an exploratory sequential design for my current research problem because it will clarify how farmers are thinking about herbicide resistance – as well as providing an appropriate dataset for identifying relevant farmer frames, place attachments, and weed management practices; as well as testing how these are related.

MIXED METHODS DESIGN

An exploratory sequential mixed methods design is particularly appropriate for my research given that I have identified both focus groups and surveys as superior ways of addressing various elements of my research problem. In an exploratory mixed methods design, the researchers begin with qualitative methods to identify topics/language/issues of interest – the results of this analysis are used to develop a larger quantitative project that tests the general applicability of the qualitative trends. Given my motivation to identify poorly understood dimensions of farmers' herbicide resistance framing, focus groups are a superior choice. Further, my motivation of testing the generalizability of these dimensions as well as latent place attachment has led me to choose survey research methods. Combining these two methods will result in the fulfillment of all of my research goals, while also ameliorating some of the weaknesses of each method. Three phases constitute my research design. The first is the exploratory qualitative phase – in this case focus groups – followed by instrument development and concluded with the administration of the quantitative instrument – in this case a survey.

FOCUS GROUP PHASE

Following Morgan (1997), we kept our focus groups relatively small, with 6-10 participants in each interview. Locations of the focus groups were selected based on pre-existing relationships with local university extension educators in states that have, or are beginning to have, herbicide resistance problems. Members of the research team had connections with extension educators in Arkansas, Iowa, Minnesota, and North Carolina –therefore focus groups were conducted within these states. Although these sites cannot be said to be representative of the U.S., they do provide a valuable cross-section of different geographies where herbicide resistance has become a significant problem. Between February and May of 2015, twelve focus group interviews were conducted in Arkansas (two focus groups), Iowa (four focus groups), Minnesota (two focus groups), and North Carolina (two focus groups). Hereafter, specific interviews are referred to using the state abbreviation followed by a number signifying time order (e.g., MN1 signifies the first Minnesota focus group).

The university extension educators who assisted in the recruiting of the interviewees expressed that they had recruited growers whom they considered to be their 'best' in terms of management practices, yield, and/or communication with extension. Our participants often stated that they were attending the focus group because they had a good relationship with the extension educator that requested their presence. Therefore our participants are more likely to be farm managers who listen to their extension educator's advice and are at the forefront of HR weed knowledge and management. Although this sample cannot express views that may be held by less knowledgeable farmers, it does reflect the values and ideas of growers who are relatively highly aware of and educated about herbicide resistance. This may have impacted the results of the focus groups, as these 'best growers' may be more innovative than typical growers in these states, as well as more involved in extension activities. Additionally, two focus groups in Iowa each had one organic grower present. This changed the dynamics of the focus groups, particularly resulting in conventional growers occasionally becoming more agitated and defensive of their management practices. For a summary of focus group demographics, refer to Table 1 in the appendix.

The focus groups were most often conducted at a university building, although several took place at community centers or restaurants. For each focus group, a primary researcher led the discussion, with a secondary researcher taking notes. The recruiting extension educator or specialist was also present at each focus group. Although having non-participants present in a focus group is not recommended (Morgan 1997), we felt it was important for the extension educators to be compensated for their role in the recruitment process. Although their presence may have influenced farmers' responses to a degree, the participants were clearly already very trusting of their extension educator and often took their advice – otherwise they would not have been at the focus groups. We also instructed extension educators to remain silent observers and not contribute to the discussion. Therefore we believe the bias to be minimized.

Focus groups lasted approximately one and a half hours each, and were audio recorded. The secondary researcher took notes on general themes while the primary researcher facilitated the discussion. Before beginning, participants were briefed on the purpose of the focus groups and encouraged to state any differing opinions during the discussion. They then filled out a consent form and a short demographic questionnaire. Following an 'ice-breaker' question, there were three main lines of questioning; 1) how a farmer *should ideally* react to herbicide resistant weeds on their own farm versus how they *would actually* react, 2) how a farmer *should ideally* react to herbicide resistant weeds on their neighbor's farm versus how they *would actually* react, and 3) whether farmers view herbicide resistance as a short- or long-term problem. These questions were open-ended and intended to prompt free discussion among farmers.

Following transcription of all the interviews, coding of the focus group data was completed in two phases as recommended by Saldana (2015). Both coding phases were completed manually. In the first phase, we followed an 'Eclectic Coding' approach in which we coded data with a variety of descriptive, emotive, versus and narrative codes based on our first impressions of passages. This method of coding is described as being particularly appropriate as an exploratory technique where multiple processes or phenomena are expected to be discerned from the data (Saldana 2015). After every few transcripts, the coders would compare coding, check inter-coder reliability, refine thematics, and discuss emerging codes.

Following this initial coding, our second phase of coding followed a code mapping approach (Saldana 2015) in which we focused on condensing codes into a list of categories. This list of categories was then used to identify overarching themes in the data. This list of categories was then used to identify overarching themes in the data. In order to better identify significance of frequently emerging themes, we also identified quotes that were representative of farmers' expressed thematic attitudes throughout the focus groups. The counts and quotes were discussed and checked for inter-coder reliability and agreement.

SURVEY INSTRUMENT DEVELOPMENT PHASE

Following the focus group coding and analysis, I, along with input from the rest of the research team, developed a survey based on the themes and ideas discovered in the focus groups. This enabled the research team to use the language and concerns of the farmers within the survey itself, eliminating confusing wording that might be interpreted incorrectly. As Creswell (2014) points out, it is difficult to develop survey items from focus group analysis. For this reason, we conducted cognitive interviews of the survey to clarify that the questioning route is clear and true to the focus group themes.

Farmers who were willing to take the survey in front of a team member and give their feedback were recruited either directly by a research team member or by extension educators the team was familiar with. The feedback given by these individuals was invaluable in refining the survey themes and wording to make sure the questions were measuring the intended constructs. Additionally, the relationships identified *during* the focus groups were used in the development of the survey research portion. For instance, we noted in the focus groups that farmers tended to distrust government officials. Therefore when creating the survey we made certain to emphasize that the survey was coming from research associated with various universities – not simply a government initiative. We also employed existing relationships with extension educators and local agricultural news sources to advertise the survey to potential respondents. Therefore the survey itself was the product of a large web of relationships – both those that existed before the start of the research (i.e. between team members and extension educators) and those that developed during the project (i.e. between the focus group facilitator and the participants).

SURVEY PHASE

A survey based on the focus group results was sent to 9,000 corn and soybean farmers across the US in winter of 2015 and spring of 2016 – with 839 returning usable. This gives us a response rate of 9.3 percent – just below the national average farmer response rate of about 10-20% (Pennings, Irwin and Good 2002). This was, largely, a result of our chosen sampling frame. We used a marketing company that maintains a list of farmer mailing and email addresses –

specifically those farmers who subscribe to certain agricultural mailing lists. Unfortunately, it appears that this list was not maintained to remove individuals who were no longer farming. Evidence of this comes from the numerous calls we received stating that the intended survey recipient had died, retired, moved on from farming, etc. Fortunately, those surveys that were returned were nearly all complete – there was very little measurement error within the surveys themselves. This is an indication that our survey instrument was appropriate for the population, despite the fact that we had difficulty reaching said population. The validity of our instrument is further confirmed by comparison with the 2012 Iowa Farm and Rural Life Poll. When comparing similarly phrased questions about herbicide resistance, our survey showed an extremely similar distribution of responses to those in the Iowa Farm and Rural Life Poll (see Tables 2 and 3). This is bracing as it indicates high reliability of these questions and validity of our instrument.

SUMMARY AND TIMELINE

The three chapter format outlined above will effectively meet all of my research goals for my dissertation. Building from a cognitive/cultural perspective to a place-based analysis enables me to capture a variety of intertwined socio-environmental factors contributing to farmers' herbicide resistant weed management. Additionally, my theoretical contribution to mixed methods enables easier replication of my research to facilitate a deeper understanding of *all* the dimensions of weed management, as well as providing a framework for studies outside of this purview. To reiterate, the primary goals of my dissertation are to 1) improve the understanding of why people, and specifically farmers, make certain behavioral/managerial decisions, 2) uncover the master frames farmers use to explain their own attitudes and actions – as well as clarifying the link between these master frames and sociotechnical imaginaries, 3) clarify how place disruption impacts farmers' place attachment and related attitudes and behaviors, and 4) contribute a theoretical rationale for mixed methods research based on relational pragmatism. It is my intention that addressing these goals will enhance the understanding of farmers' herbicide resistant weed management in order to better address the adoption of sustainable integrated management tools. This study in turn will provide insight into how farmers may deal with other unintended consequences of conventional agriculture. By integrating a conjoint socio-environmental understanding of farmers' attitudes and practices related to herbicide resistance I will address a gap in the current herbicide resistance literature while also contributing to the advancement of a sociology that considers social and environmental factors in tandem.

In addition to these contributions to sociology, my dissertation makes several practical contributions useful in agricultural policy, education, and methods design. I address how we might better advance sustainable agriculture through the understanding of farmers' place attachment and master frames. This understanding of farmers' decision making processes will aid in the formation of programs and policies geared at developing a sustainable agricultural system. Additionally, I advance a theoretical framework for the development and use of mixed methods that has practical implications both for research in sociology and within/across other disciplines.

This chapter serves as an introduction to my three-chapter dissertation. Following this, I will cover chapters 1, 2 and 3 as outlined above. Finally, I end with a chapter that mirrors this one to draw together conclusions from my three separate chapters

APPENDIX

Table 1. Demographics of Focus Group Participants by State

	Minnesota	Iowa	North Carolina	Arkansas
Number of Focus Groups	2	4	2	2
Number of Participants	16	25	11	12
Males	16	23	11	12
Age	32 - 68	33 - 77	44 - 79	24 - 73
White	16	25	8	11
Acres Managed	200 - 6,200	110 - 6,000	0 - 1,600	2,200 - 9,200
Acres Owned	0 - 2,600	0 - 1,500	0 - 900	40 - 2,200
Farms with Partner	12	18	5	10
Grows Corn	16	25	8	9
Grows Soybeans	16	25	10	12
Grows Cotton	0	0	0	8

Table 2. 2016 AFRI Herbicide Resistance Survey

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
When new weed management technologies are introduced, it is only a matter of time before pests evolve resistance	0.7%	4.2%	13.2%	55.5%	26.5%
Seed and chemical companies need to do a better job of keeping up with the evolution of resistance in weeds	3.1%	7.3%	30.7%	41.8%	17.1%
By the time a weed develops resistance to an herbicide, at least one new herbicide will have been found to replace it	20.9%	37.7%	25.0%	13.8%	2.6%
Modern agricultural practices contribute to the conditions that spur evolution of herbicide resistant weeds	4.6%	7.2%	19.6%	46.5%	22.1%
Any new chemical mode of action that is developed to control weeds will be overused	3.9%	9.5%	25.5%	45.9%	15.1%

Table 3. 2014 Iowa Farm and Rural Life Poll

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
When new pest management technologies are introduced, it is only a matter of time before pests evolve resistance	0.8%	2.2%	15.0%	58.8%	23.2%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Seed and chemical companies need to do a better job of keeping up with the evolution of resistance in weeds	1.6%	5.7%	26.9%	49.2%	16.6%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Herbicide-resistant weeds are not a major concern because new technologies will be developed to manage them	20.3%	43.6%	22.1%	12.9%	1.0%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
The way that farmers use pest management technologies does not really impact the rate at which resistance evolves (Note that this question is the reverse of its coordinating question in the AFRI survey)	26.3%	40.6%	18.3%	11.7%	3.1%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Poor management by a few farmers leads to premature evolution of resistant pests	1.7%	7.7%	21.7%	45.0%	23.8%

CHAPTER 1

"I would say that might be all it is, is hope":
The Framing of Weed Resistance and How US Farmers Explain their Faith in Herbicides

INTRODUCTION

United States corn and soybean farmers' use of herbicides as the primary method of weed control persists in spite of increasing concern over herbicide resistance (Boerboom and Owen 2006; Egan 2014). The herbicide glyphosate, marketed by Monsanto under the brand name Roundup, and by many other companies under many different names, presents an interesting problematic. Glyphosate is applied to control weeds in glyphosate-tolerant crop varieties on 93 percent of soybean acres and 85 percent of corn acres in the US as of 2015 (Livingston et al. 2015). Reasons for this widespread use of glyphosate include low cost per acre, relative ease of use, ability to kill grasses and broadleaf weeds, and comparatively low environmental and health risks (Bullock and Nitsi 2001; Hammond, Luschei, Boerboom and Nowak 2006; Gusta, Smyth, Bekcher, Phillips and Castle 2011; Livingston et al. 2015). These factors are particularly appealing to farmers bound by economies of scale and productivist pressures in the US, making glyphosate use emblematic of the problems facing both herbicides in general and conventional US agriculture at large.

However, as with many technologies, there have been unintended consequences of relying on a single herbicide for weed control – for instance herbicide resistant (HR) weeds. These weeds are the result of selective pressure when a single herbicide is the primary method of weed control used on a field year after year. For instance, due to the widespread use of glyphosate since 1996, sixteen weed species have developed glyphosate resistance in the US (Heap 2016). This presents a serious problem for farmers who have come to rely on glyphosate, as weeds that are not controlled result in crop yield loss, reduced commodity prices due to weed seed contamination, reduced land values, and increased costs when implementing alternative control methods (Norsworthy et al. 2012). In Georgia and Arkansas, the presence of glyphosate-resistant Palmer amaranth, a particularly fast growing and productive weed, has increased management costs in cotton by $48/ha (Norsworthy et al. 2012).

The increase in US acreage of resistant weeds has led experts to be more vocal in recommending an integrated weed management (IWM) approach (Gould 1995; Hammond et al. 2006; Vanlauwe, Bationo, Chianu, Giller, Merckx, Mokwunye, Ohiokpehai et al. 2010). This is similar to the integrated approaches advocated in insect and disease management, and is meant to combine preventative, mechanical, cultural, chemical, and biological weed management techniques. When used together, these practices provide more effective weed management and reduce the risk of weed resistance, thus increasing the longevity of current herbicides (Barman et al. 2014; Harker 2013; Llewellyn et al. 2004).

In spite of farmers' recognition of the benefits of IWM, there has been limited adoption of multiple control tactics for weed management (Binimelis et al. 2009; Johnson et al. 2009; Llewellyn et al. 2004; Webster and Sosnoskie 2010). Reasons cited for this reticence to move way from chemical-dependent weed control include high economic and temporal costs, as well as a strong and persistent trust in the future development of new herbicides to take the place of those that are no longer effective (Bonny 2016; Livingston et al. 2016; Norsworthy et al. 2012; Webster and Sosnoskie 2010). This common faith in the development of new herbicides persists despite the lack of discovery of any new herbicide mode of action in the last 20 years (Boerboom and Owen 2006; Bonny 2016; Norsworthy et al. 2012), a trend which seems unlikely to change in the near future (Norsworthy et al. 2012; Johnson et al. 2009).

This paper addresses farmers' trust in chemical weed control, asking why farmers continue to use herbicides and eschew IWM in light of limited herbicide discovery, as well as how they explain their continued use of a chemical-dependent weed management plan to themselves and others. This paper is intended as a case study of conventional, technology-dependent agriculture and how sociology can contribute to a better understanding of and movement towards sustainable integrated practices. To approach this topic, I draw on the literatures of sociotechnical imaginaries and master frames. I propose that farmers' seeming trust in chemical technology is an 'as-if' trust – that is, a statement born of the belief that one is dependent on external actors/systems and has no other choice, obscuring deeper feelings of helplessness and mistrust (Carolan 2006; Wynne 1992; 1996). In essence, as-if trust grows from structurally binding situations in which actors lack agency and instead must rely on systems they have little hope of affecting. In order to support this 'as-if' trust, I suggest that farmers draw on master frames that are iteratively supported by the dominant sociotechnical imaginary of weed control in US conventional farming systems today.

THEORETICAL BACKGROUND

I adopt a perspective of master frames and imaginaries for several reasons. Sociotechnical imaginaries provide imagined futures supported by specific technologies, which in turn suggest a trajectory of research and innovation to achieve these futures (Eaton, Gasteyer, and Busch 2014). They are less a theory of how society functions and more an idealistic view of how technology can support an envisioned future. Master frames, in turn, constitute culturally resonant, general, symbolic repertoires of interpretation that are drawn upon by a variety of actors to identify problems, specify grievances, and justify goals (Benford 2013; Berbrier 1998; Gerhards and Rucht 1992; Swart 1995). They provide a tool box from which interpretations can be drawn in order to understand or justify certain situations and actions (Oliver and Johnston 2000). Therefore, they have the potential to interact with sociotechnical imaginaries in that master frames justify the goals and strategies suggested by such imaginaries. Additionally, the resonance of master frames may be increased by ascription to a certain sociotechnical imaginary, resulting in an iterative support cycle. This interaction of sociotechnical imaginaries and master frames will aid in understanding the processes of trust and meaning-making that farmers are going through when they a) express hope or faith in new herbicide development and b) continue to use an herbicide-dominant management plan despite understanding the benefits of IWM (Binimelis et al.2009; Carolan and Stuart 2015; Johnson et al. 2009).

SOCIOTECHNICAL IMAGINARIES

Sociotechnical imaginaries are defined by Janasoff and Kim (2009) as "collectively managed forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (p. 120). They reflect attainable, prescribed, and desired futures by promoting collective visions of 'good society' that are achievable through certain technologies. Therefore they also function to validate certain trajectories of research and innovation over others and obscure obstacles in order to justify the investment in these technologies (Eaton, Gasteyer and Busch 2014; Janasoff and Kim 2009). These imaginaries, rather than being individualistic in nature, are embedded in social organizations and produce systems of meaning that enable collective interpretations of reality (Janasoff and Kim 2009).

The dominant sociotechnical imaginary of US conventional agriculture revolves around increasing productivity by continuously improving technological innovation. The envisioned 'good' society of this imaginary is one in which agriculture produces large quantities of crops for food, fuel, etc. on limited and/or degraded land through the application of technologies. It is fundamentally a commercial enterprise, focused on intensification, specialization, mechanization, and technological innovation with the goal of securing national self-sufficiency for agricultural commodities (Wilson 2001). Plant breeding, synthetic fertilizers, pesticides, herbicides, and irrigation are all innovations that have contributed to the rise of high-yield monocultures – an example of how technological solutions contribute to the increasing intensification of agriculture (Tomlinson 2013). Thus US agriculture trends towards monocultures, chemical intensive management, and high-capital systems that are heavily reliant on technological innovation to achieve their productivist goals (Lang and Heasman 2004; Lawrence et al. 1995; Lyson and Gillespie 1995; Tomlinson 2013). The dominant US agriculture imaginary is closely tied to this productivist trend, including its high dependence on technology and confidence that this technology can regulate and control the environment for the increasing productivity of agriculture.

In the context of productivist pressures, technological innovations, such as genetic engineering, are often promoted as "magic bullets" that will allow farmers to "feed the world" through increased productivity (McDonagh 2014). In combination with genetically modified crops, glyphosate is one of these “magic bullets”, capable of simplifying weed control, reducing soil erosion, limiting environmental pollution, and enabling farmers to manage more acres and thus become more ‘productive’ (Binimelis, Pengue and Monterroso 2009; Duke and Powles 2008; Egan 2014; Harker 2013; Livingston et al. 2015). However, while many farmers trust that a new herbicide will be developed to replace glyphosate (Bonny 2016; Livingston et al. 2016; Norsworthy et al. 2012; Webster and Sosnoskie 2010), a new mode of action has not been discovered since 1998 (Norsworthy et al. 2012; Webster and Sosnoskie 2010). Even if a new herbicide were to be discovered, it would take about 11 years for it to reach the market (Johnson and Gibson 2006). Combined with the surge in resistant weeds, this lack of development presents a challenge to the sociotechnical imaginary of US agriculture that prioritizes productivity through, among other technologies, the application of synthetic inputs such as synthetic inputs (Tomlinson 2013; Wilson 2001).

Contrary to the promotion of herbicides as a technology fundamental to the continued productivity of US agriculture, it appears that *less* advanced technologies may be the key to solving herbicide resistant weed problems. Hand-pulling, chaff carts, burning of weeds, crop rotation, and cultivation are all low- or old- tech components of Integrated Weed Management (IWM) programs designed to stop herbicide resistance and maintain the effectiveness of current herbicides (Harker 2013; Jacobs and Kingwell 2016; Zoschke and Quadranti 2002). However, even though farmers are aware of the problem of herbicide resistance (Owen, Hartzler and Pringnitz 2014), stated trust in the development of new herbicides remains high while adoption of IWM practices remains low for US farmers (Bonny 2016; Llewellyn et al. 2004; Livingston et al. 2016; Norsworthy et al. 2012; Webster and Sosnoskie 2010). This is especially true for those with no direct experience with herbicide resistance (Dentzman, Gunderson and Jussaume 2016; Llewellyn et al. 2004). Although herbicide resistant weeds, and particularly glyphosate resistant weeds, are presenting a challenge to the dominant US agricultural sociotechnical imaginary, farmers continue to use herbicides as their primary weed control method. I attempt to clarify this discrepancy by drawing on the framing literature to show how farmers employ master frames to explain their apparent trust in the chemical industry and continued use of herbicide-reliant weed management as part of an increasingly fragmented sociotechnical imaginary.

FRAMES AND MASTER FRAMES

Frames have been used in studies related to agriculture to understand: why farmers resist conservation tillage in the presence of profit frames (Andrews, Clawson, Gramig, and Raymond 2013), how academic ‘experts’ and farmers conceive of biodiversity and ‘good’ crop varieties in contrasting ways (Soini and Aakkula 2007; Tisenkopfs, Kunda, and Sumane, 2014), and why tobacco farmers hold seemingly oppositional attitudes and practices related to tobacco production and consumption (Wright 2005). Additionally, the concept of master frames has been used to investigate why organic and conventional agricultural movements draw on similar concepts to support diverse ideas about how farming should be done (Lockie and Halpin 2005), as well as how farmers interpret their oppression in a developing capitalist economy and articulate strategies for redress (Mooney and Hunt 1996). I build on these studies by applying the concept of master frames to produce an understanding of why farmers trust and rely on herbicidal weed management plans, specifically looking at how master frames are brought into alignment and resonate with the agricultural sociotechnical imaginary. I first provide a general review of frames before describing master frames in more detail.

Frames are cognitive devices that "help to render events or occurrences meaningful and thereby function to organize experience and guide action" (Benford and Snow 2000, p. 614). They focus attention on what is relevant and away from extraneous information as well as answering the question 'what is going on here?' (Goffman 1974; Johnson and Noakes 2005). When confronted with a set of potential realities, individuals and groups can apply frames to evoke a certain interpretation and guide their understanding (Edelman 1993; Kaufman, Elliot and Shmeuli 2003). That is, master frames highlight certain bits of information and make these more noticeable, meaningful, and memorable. In addition to this highlighting, frames are also "…defined by what they omit" (Entman 1993 p. 54) such that certain possible definitions, solutions, and explanations are not considered. In these ways, frames act as prognostic, diagnostic, and motivational tools (Snow and Byrd 2007). In a prognostic sense, they help identify and justify 'what is to be done' in a given situation – i.e. a proposed solution. Similarly, a diagnostic dimension helps to attribute blame and answer the question 'what went wrong?' Finally, a motivational dimension of framing helps answer the question of why an individual should care about or act on an issue.

Although framing has seen increased use as a theoretical concept, it has also been criticized as being scattered, too static or ambiguous, and theoretically and empirically vague (Entman 1993; Gamson, Croteau, Hoynes and Sasson 1992; Scheufele 1999; Van Gorp 2007). These characteristics can threaten the benefits of a framing perspective – such as a balance between structure and agency and a bridge between culture and cognition (Gamson 1992; Van Gorp 2007). Part of the issue with the framing perspective is that 'frames' are used by different disciplines and individuals within those disciplines to mean a variety of things. Framing has been used to refer to principles of selection, decision-making conceptualizations, central story-lines of an issue, subtle alterations in presentation of a choice problem, structured understandings of how the world functions, and orienting rhetorical devices (Druckman 2001). It has also been variously used as a verb or a noun – i.e. a way of saying something versus a way of thinking (Druckman 2001; Kaufman, Elliot and Shmueli 2003).

In order to help clarify and bring order to the framing literature, Scheufele (1999) proposed a four-cell typology of framing useful for defining and categorizing studies using this concept. First, he draws a difference between 'media frames' and 'individual (or audience) frames'. Media frames are considered to be persuasive devices embedded in discourse, similar to Druckman's (2001) 'frames in communication'. In contrast, individual or audience frames are internal structures of the mind that guide thought and interpretation – similar to Druckman's 'frames in thought'. Each of these types of frames can be categorized as either the independent or dependent variable of study. This yields four types of framing studies; 1) independent media frames, focusing on how communication frames influence individual perceptions, 2) dependent media frames, looking at how communication comes to be framed in certain ways, 3) independent individual frames, looking at how individual frames influence individual perception of an issue, and 4) dependent individual frames, looking at what influences the establishment and construction of individual frames (Scheufele 1999).

Building on the above typology, social movements literature adds another dimension to the framing concept. This is an action dimension, in which a clarification is made between an individual's understanding of an issue and their *action* resulting from this cognition (e.g. McVeigh, Myers and Sikkink 2004; Polletta and Ho 2006; Tarrow 1992). Social movements literature uses this action dimension to understand how certain media/communication frames impact both individual frames *and resulting actions*. In this sense, frames can be used to clarify how individuals and groups understand and justify certain actions and events – such as joining a specific protest or mobilizing as part of a social justice group (Gamson 1992). Taking this use into context with Scheufele's typology, I situate my study of framing at the nexus of independent individual frames and resultant behaviors/actions that farmers take. I will therefore be applying the concept of frames to understand how corn and soybean farmers draw on societally relevant frames of interpretation to make sense of and explain their seeming trust in chemical management as well as their actual weed management practices.

Of particular interest to my study is the concept of master frames and how they are drawn upon by farmers to make meaning of certain beliefs and behaviors. Master frames are of more general relevance than regular frames and can be drawn on by a variety of groups to help make sense of or validate certain situations, actions, and events – including prognostic, diagnostic, and motivational elements (Snow and Byrd 2007; Wolfmuller 2009). Master frames are culturally and historically resonant stable groupings of ideational elements, such as injustice or anti-imperialism, which can be used to rationalize the goals of different groups (Benford 2013; Berbrier 1998; Markowitz 2009; Snow and Benford 1992; Steinberg 1998; Swart 1995). Such frames are unique in that they are elastic, flexible, and inclusive as well as being shaped by structurally rooted collective life experiences (Benford 2013; Hurst 2008). They constitute a cultural repertoire of interpretations that a wide variety of groups can draw from in order to understand, validate, and explain their beliefs and actions (Mooney and Hunt 1996; Snow and Benford 1992; Van Gorp 2007). They tend to fall under the category of independent individual frames, focused on how actors' understanding of a given master frame impacts their perception of an issue and potential resulting actions.

In the context of social movements studies, master frames are generally understood as central interpretive frameworks that transcend single issues and find cross-movement utility (Carroll and Ratner 1996; Snow and Benford 1992). As with social movements' use of framing more generally, master frames are applied to understand how movement actors understand, justify, and carry out certain beliefs *and* actions via movement mobilization. Although sometimes defined by their adoption by multiple social movements (e.g. Snow and Benford 1992), a master frame need not have this characteristic and can rather be defined by "…resonance with the cultural, political, or historical milieu in which it emerged" (Swart 1995; p. 468). An example is Mooney and Hunt's (1996) work with master frames in US agriculture. They determined that at least three primary master frames are relevant. These were agrarian fundamentalism, competitive capitalism, and producer-as-beneficiary, all of which provide critique capitalist agriculture in the US economy and resonate with the cultural and historical milieu of farming in the US. These master frames, Mooney and Hunt assert, act as persistent ideological themes across time, creating a repertoire of interpretations that can be drawn from to (re)construct ideological claims (Mooney and Hunt 1996). However, if master frames lose resonance they may engender frame dissonance – which can in turn lead to frames going into abeyance. Abeyance is understood as a type of 'frame hibernation', in which master frames that are not supported by local structural conditions fall out of common use in the cultural repertoire of interpretations – although they are not gone forever and may return when conditions are right (Mooney and Hunt 1996).

The adoption and effectiveness, i.e. potency, of a master frame is dependent on several factors. Firstly, the relative openness and general applicability of a master frame will determine how likely it is to resonate with a wide variety of groups. Secondly, frame resonance largely determines whether a master frame is legitimated and adopted. Resonance itself depends on empirical credibility, experiential commensurability, and narrative fidelity (Snow and Benford 1992). Empirical credibility is present when evidence of certain problems matches the master frame's interpretation of problems. Experiential commensurability involves personal experiences that match the claims of the master frame. Finally, narrative fidelity occurs when the frame is consistent with a group's larger beliefs and ideologies – a relationship I expect to find between farmers' herbicide resistance master frame and the agricultural sociotechnical imaginary.

Master frames are more likely to resonate in these ways when they have undergone alignment – a process by which actors transform a master frame to be culturally, locally, and historically relevant (Swart 1995). There are several forms of alignment used by different groups, including frame bridging, frame amplification, frame extension, and frame transformation. These alignment techniques, respectively, involve linking congruent frames, clarifying and invigorating a frame to bear on a particular issue, widening a frame to appeal to outsiders, and incorporating new values while rejecting the old (Tarrow 1992; Snow, Rochford, Worden and Benford 1986). Thus master frames, as a cultural repertoire of interpretations, may be adapted in various ways by different movements or actors to justify their specific grievances and goals in line with socio-historical situations and movement agendas.

Applied to the problem of herbicide resistance, I ask what master frame US corn and soybean farmers are drawing on to explain their apparent trust and continued use of herbicides. I anticipate that this master frame will have resonance with the sociotechnical imaginary of US agriculture and that farmers will apply frame amplification to make their master frame align with productivist and technological goals. However, there is also the potential for master frames to fail to resonant – particularly through changes in experiential commensurability and narrative fidelity – and therefore go into abeyance (Mooney and Hunt 1996). I do not discount the possibility that herbicide resistance, given its nature as a difficult problem unlikely to be solved by simple technology solutions, is creating frame dissonance and potentially heralding the abeyance of a master frame related to the agricultural sociotechnical imaginary.

SUMMARY

Through the confluence of sociotechnical imaginaries and master frames I aim to understand how farmers interpret different weed management practices related to the larger cultural and technological milieu in which they are situated. Drawing from the use of master frames in agricultural studies, I build on this concept by incorporating the sociotechnical imaginary of US agriculture. I suggest that this productivity imaginary supports and is supported by a dominant master frame that justifies its goals and technological means of achieving them. Farmers are then able to draw on this master frame to validate their trust and adherence to a sociotechnical imaginary that is failing them in terms of failed weed control because of weed resistance. Alternatively, frame dissonance may occur as technological answers to herbicide resistance fail, opening up the possibility that some farmers are losing experiential commensurability and becoming disillusioned with the US agriculture sociotechnical imaginary.

METHODS

In order to explore the master frames that farmers employ, I use focus groups to explore how US corn and soybean farmers think about herbicide resistance and explain their views and weed management actions. Following Morgan (1997), we kept our focus groups relatively small, with 6-10 conventional corn and/or soybean farmers in each discussion. Locations of the focus groups were selected based on pre-existing relationships with local university extension educators in states that have, or are beginning to have, herbicide resistance problems. Members of the research team had connections with extension educators in Arkansas, Iowa, Minnesota, and North Carolina –therefore focus groups were conducted within these states. Although these sites may not be representative of the US, they do provide a valuable cross-section of different geographies where herbicide resistance has become a significant problem. Between February and May of 2015, ten focus group interviews were conducted in Arkansas (two focus groups), Iowa (four focus groups), Minnesota (two focus groups), and North Carolina (two focus groups). Hereafter, specific interviews are referred to using the state abbreviation followed by a number signifying time order (e.g., MN2 signifies the second Minnesota focus group).

The university extension educators who assisted in the recruiting of the interviewees recruited growers whom they considered to be their 'best' in terms of management practices, yield, and/or communication with extension. Our participants often stated that they were attending the focus group because they had a good relationship with the extension educator that requested their presence. Therefore, our participants are more likely to be farmers who listen to their extension educator's advice and are at the forefront of HR weed knowledge and management. Although this sample cannot express views that may be held by less knowledgeable farmers, it does reflect the values and ideas of growers who are relatively aware of and educated about herbicide resistance. This may have impacted the results of the focus groups, as these 'best growers' may be more innovative than typical growers in these states, as well as more involved in extension activities. Additionally, two focus groups in Iowa each had one organic grower present. This changed the dynamics of the focus groups, particularly resulting in conventional growers occasionally becoming more agitated and defensive of their management practices. For a summary of focus group demographics, refer to Table 4 in Appendix A.

The focus groups were most often conducted at a university building, although several took place at community centers or restaurants. For each focus group, a primary researcher led the discussion, with a secondary researcher taking notes. The recruiting extension educator or specialist was also present at each focus group. Although having non-participants present in a focus group is not recommended (Morgan 1997), we felt it was important for the extension educators to be compensated for their role in the recruitment process. Although their presence may have influenced farmers' responses to a degree, the participants were clearly already very trusting of their extension educator and often took their advice – otherwise they would not have been at the focus groups. We also instructed extension educators to remain silent observers and not contribute to the discussion; we believe the bias was minimized.

Focus groups lasted approximately one and a half hours each, and were audio recorded. The secondary researcher took notes on general themes while the primary researcher facilitated the discussion. Before beginning, participants were briefed on the purpose of the focus groups and encouraged to state any differing opinions during the discussion. They then filled out a consent form and a short demographic questionnaire. Following an 'ice-breaker' question, there were three main lines of questioning; 1) how a farmer *should ideally* react to herbicide resistant weeds on their own farm versus how they *would actually* react, 2) how a farmer *should ideally* react to herbicide resistant weeds on their **neighbor's** farm versus how they *would actually* react, and 3) whether farmers view herbicide resistance as a short- or long-term problem. These questions were open-ended and intended to prompt free discussion among farmers.

Following transcription of all the interviews, focus group data coding was completed in two phases as recommended by Saldana (2015). Both coding phases were completed manually. In the first phase, we followed an 'Eclectic Coding' approach in which we coded data with a variety of descriptive, emotive, versus and narrative codes based on our first impressions of passages. This method of coding is described as being particularly appropriate as an exploratory technique where multiple processes or phenomena are expected to be discerned from the data (Saldana 2015). After every few transcripts, the coders would compare coding, check inter-coder reliability, refine thematics, and discuss emerging codes.

The second phase of coding followed a code mapping approach (Saldana 2015) in which I focused on condensing codes into a list of categories. This list of categories was then used to identify overarching themes in the data. Specifically, I compiled a list of categories that constitute a given master frame – i.e. a line of thinking or standard repertoire that was consistently drawn upon to explain herbicide resistance or explain why they use certain management practices. In order to better identify significance of frequently emerging framing devices, I also identified quotes that were representative of farmers' expressed thematic attitudes throughout the focus groups.

FINDINGS

Several major themes emerged in response to our focus group discussions on weed management. These themes were brought up in every focus group and constituted main repertoires of interpretation which participants drew upon to both understand herbicide resistance and make meaning of their actions towards it. Specifically, two of the most common themes used to explain herbicide resistance and farmers' actions were 1) the feasibility of herbicide solutions and 2) farmers' management of herbicides. These themes account for prognostic and diagnostic dimensions of a techno-optimism master frame, wherein technology is viewed as the *solution* but never the *cause of the problem*. Techno-optimism, as proposed by Wienberg (1966/1981), posits that social and environmental problems can be fixed through the application of technology rather than the alteration of human behavior. It has often been applied to environmental problems, for example by Lomborg (2008) and Simon (1981), to claim that "technological breakthroughs will serve as the means to address each and every environmental problem that arises, allowing society to overcome natural limits and all socio-ecological challenges" (York and Clark 2010, p. 481).

Although a techno-optimism frame was dominant throughout the focus group discussions, there was also some limited challenging of this frame, hinting at decreasing resonance of a techno-optimism master frame. It is possible that farmers are increasingly faced with experiential incommensurability as new herbicides fail to emerge and rescue agriculture from the specter of weed resistance, prompting some challenging of the frame. For a summary of the techno-optimism master frame, its components, and their themes, see Table 5 in the Appendix.

THE FEASIBILITY OF HERBICIDES – A PROGNOSIS

When asked what a farmer should or would do in response to herbicide resistant weeds on their farm, the most common response from focus group participants was some kind of herbicide-based management. However, this is not to say that farmers are unaware of the herbicide resistance problem or how it occurs. In fact, proposed management solutions often emphasized the need to rotate herbicide modes of action, mix multiple modes of action in one application, include pre-emergent and residual herbicides, time applications carefully, and use the full suggested rate of herbicides to decrease the chance of further resistance development. The following quote from a grower in Iowa was typical:

> **IA3:**
> Participant: "I mean as a producer, I mean the first thing I would look at is an alternative mode, or dual modes, or as many layers of action as you can get on that aren't identical to the practice you had that year."

Although non-chemical management practices were also mentioned, they were less emphasized and often discussed as a significantly less desirable alternative. Additionally, they constituted supplementary practices to a primarily herbicide-based weed management plan. For example, cover crops and tillage were two of the most commonly cited cultural practices for enhancing resistant weed management. However cover crops were undesirable due to the difficulty of establishment, low monetary return, and occasional difficulty killing the cover when it came time to plant corn or soybeans. Likewise, tillage was seen as a somewhat effective but impractical solution due to erosion, government regulation of Highly Erodible Lands, time commitment, and the decreasing familiarity of young farmers with cultivators. Their incorporation into weed management was not seen as a long term solution, but rather a stalling tactic while waiting on a new herbicide to become available:

IA1:
Participant: "I think we're all probably hoping somewhere in that chemistry, there's something that comes around that's a new version. Yeah, stall long enough, maybe they'll figure something out, give us another product. That's about it."

MN2:
Participant: "In other words, trying to keep a company keeping new products moving in the pipeline – because that's what's eventually is going to have to happen is…this is never going to go away. You're always going to have an issue with whatever herbicide comes out. So keeping new options coming is more important than really the agricultural practices and all that."

This feasibility of a new herbicide being developed to deal with herbicide resistance was the single most consistent and forceful theme of the focus group discussions – a strong prognosis answering the question 'what is to be done?' Participants emphasized that new herbicides *could* be developed, even if they weren't seeing that right now:

AR2:
Participant: "Well, the one thing that we don't know anything about is what new chemistry is coming. But the more that we have resistance, the harder they're going to work to find something. […] We're too big of an industry not to."

NC2:
Moderator: "So do you think this will be a short-term or a long-term problem?"
Participant: "I think with the technology, it'll probably be short-term."
Moderator: "And what kind of technology?"
Participant: "Well, controlling bad weeds, you know, that these companies find out about them, they go right then and experiment, trying to figure a way to take them out, because if they do, and they can get a product that doesn't harm the crop, then they've got some money in the bank."

This matches with participants' experiential commensurability – multiple growers recalled that up until this point, a new herbicide *has* been marketed to supplement those that have become resistant. When weeds, including common lambsquarters, developed resistance to atrazine, farmers turned to ALS inhibitors to manage these weeds. When Roundup Ready soybeans were registered for use, glyphosate quickly replaced the use of ALS inhibitors in soybeans because glyphosate was more effective on a broad range of weeds, was easy to use, had a wide application window, and did not restrict planting of other crops in rotation. Therefore, the fact that no new herbicide modes of action have been discovered in 20 years, and may not ever be, does not resonant well with farmers' experiences. A discussion from a focus group in Arkansas emphasizes this, as the participants believe a new effective chemistry is possible if only chemical companies would try harder:

> **AR1:**
> Participant 1: "I'm a little discouraged with the chemical industry. I think -- I don't think they're looking at the opportunity…I think it just -- I think the chemical company just rolled over and held her hands up. [They] just want to throw some 2,4-D at it. What? That's baloney. Those people are supposed to be intelligent. Well, duh."
> Participant 2: "I agree, totally."
> Participant 3: "You can't tell me that it can't be done. You can't tell me that there ain't a chemical out there to kill that weed. I will never believe it."

Even though these growers recognize that a new herbicide mode of action hasn't been developed in some time, the *feasibility* of a new herbicide being discovered, developed, and marketed was commonly referenced and relied upon as a continuing solution to herbicide resistance problems. In short, it is the prognostic dimension of the techno-optimism master frame. Our focus group participants seemed to retain a certain trust that such a solution was possible, placing their faith in the type of technology that had saved them in the past and that fits with the narrative of a productivist agricultural sociotechnical imaginary.

MANAGEMENT AS THE PROBLEM – A DIAGNOSIS

If herbicide resistance is the problem and herbicides the only feasible solution in farmers' eyes, then growers must shift the blame for herbicide resistance away from the herbicides themselves. Fitting with this narrative, focus group participants consistently placed the blame for herbicide resistance not on the technology itself but on farmers' misuse or mismanagement of it. Specifically, using glyphosate year after year, cutting suggested rates of application, and poor timing were all referenced as management issues that were at fault. For instance a grower in Iowa reflected that;

IA4:
Participant: “But when I was a little guy, they’d wait until the weeds were this tall, and burn them down, and then plant into them, and then come back later, and spray Roundup again. That’s kind of why we’re probably having this meeting, I imagine.”

Other growers expressed similar opinions, stating that poor management was the true issue:

AR2:
Participant: “Well, we set ourselves up for the perfect storm, get folks cutting rates, and everything else. And now, we’re dealing with it now.”

AR2: "Well, that’s part of the problem. When a company comes out with a chemical, they charge you as much as they can until they think that you will still buy it. So, what do we do, if it works so well, we cut the rates, and that adds to our resistance problem.”

The perceived mismanagement of herbicides, which focus group participants saw as a key cause of herbicide resistance, was also discussed in reference to farm size. It was recognized that herbicides, and glyphosate in particular, had enabled the expansion of farms to a very large scale. This scale was seen as necessary to both make a living and to feed the growing world population. However, there was also the recognition that growing farm sizes trap farmers in a chemical weed management plan, as well as making proper management of herbicides more difficult.

MN1:
Participant 1: “And you look at some of those farmers, the bigger farmers, and you wonder how in the heck they’re ever going to be able to do that [precision applied herbicides; rotated herbicides]. It’s just – the size matters, you know, the size of the operation.”
Participant 2: “Roundup definitely allowed people to get bigger because it worked so good for so long that you could double your acres easily and get the work done. But I don’t see the cultivator coming back.”
(laughter)
Participant 1: “No, I don’t see it coming back, that’s right.”
Participant 2: “I think we’re going to have to find chemicals.”
Participant 1: “Yeah, you’re right.”

AR2:
Participant: "It's changed so much. Now you got to farm so much land to keep your head above the water, and you got to buy you another spray rig, you got to do that. That's pitiful. But anyhow, we're having to do it. And it puts a crunch on your time. You can't get around it, you know, in the manner you'd like to."

These sentiments avoid blaming herbicide technologies for their own weed resistance problems, and rather define the problem – i.e. the 'what went wrong?' – as one of management that is made increasingly difficult with the growing size of farms. Given that a large farm size is viewed as necessary, however, growers have difficulty envisioning a weed management plan that isn't reliant on herbicides;

IA3:
Participant: "The farm sizes have got to the point where you can't mechanically do it anymore. You can't get it accomplished."

IA4:
Participant: "And chemicals has changed everything to the point where, you know, an extremely large operation with not much manpower can farm a lot of acres, because they are -- we have all become chemical reliant."

These statements reflect the same techno-optimism master frame that farmers' draw upon to explain their faith in the feasibility of herbicide development. Not only are herbicides seen as the *only* possible solution for the problem of maintaining farm sizes large enough to turn a profit and feed the world, they are also relieved of the stigma of inherently causing their own resistance problems. Instead, the farmers blame themselves, or other 'bad' farmers, for mismanagement of a tool. That is, the tool is not broken or unsustainable in-and-of itself – it simply needs to be used more carefully.

Still, there were growers in our discussions who recognized the unlikelihood of this scenario should a new 'miracle herbicide' come on the market;

AR1:

> Participant: "If you give me a silver bullet, I'm going to use it. And I'm probably going to overuse it. Because we get behind...and you get in a bind, and you're going to say 'Well, I've got this, I'll just fall back on that'."
>
> **AR1:**
> Moderator: "I mean, do you guys expect there to be something that comes out that's like Roundup was? Do you think that's a possibility?"
> Participant 1: "I don't see why not."
> Participant 2: "But then I'm pessimistic. How long will it last? You know, how long before it gets around?"
> Participant 1: "That's the second thought every time, is how long is it going to last."
> Participant 2: "Because we're all going to use it."
> Participant 3: "Overuse it."

While recognizing that good management of an herbicide is vital to its longevity, these growers also recognize the bind in which they find themselves. With huge farm sizes, high production demands, and increasing environmental regulations, farmers recognize that if a new miracle herbicide were to be released they would end up overusing it – not because they don't understand the process of herbicide resistance, but because conventional agriculture has trapped them in a situation where other options are too time and money consuming to consider. Additionally, the sociotechnical imaginary of agriculture limits what solutions are seen as desirable and feasible, specifically promoting input-heavy technological solutions to support increasing yields.

This conundrum likely drives part of farmers' faith in the feasibility of herbicides – they are forced to trust and use them because they see no other option. It isn't as if farmers believe new herbicides can be developed quickly and easily – rather they are forced to place their trust in the potential of new herbicides being developed *at some point*. They are caught in a structural bind where they have become dependent on herbicides, prompting an 'as-if' trust that is espoused because farmers see no other choice. This is further emphasized by the occasional challenges focus group participants made to the master frame of techno-optimism.

CHALLENGING THE FRAME

Earlier in this paper, I presented a quote from a farmer in Iowa who suggested that stalling practices should be used until the real solution, a new herbicide, was developed. However, I did not include another farmer's response to that statement, which is quite elucidating;

> **IA1:**
> Participant 1: "I think we're all probably hoping somewhere in that chemistry, there's something that comes around that's a new version. Yeah, stall long enough, maybe they'll figure something out, give us another product. That's about it."
> *Participant 2: "That's the hope. I would say that might be all it is, is hope."*

The second participant in this conversation states rather openly what some participants only hint at; that their faith in the feasibility of a new herbicide being developed may be nothing more than an empty hope; an 'as-if' trust. Although less persistent and intense than farmers' framing of herbicide resistance as a problem that can and will be solved through herbicide development, challenges to the techno-optimism master frame did exist. Several of these centered around farmers' experiences with and education on the possibility of new herbicides:

> **IA3:**
> Participant: "At this particular juncture, there does not appear to be any new technological developments that are going to fix the problem like Pursuit fixed the Atrazine problem."
>
> **AR2:**
> Participant: "They keep telling us there's nothing out there to be developed, there's nothing being worked on, so. All we're getting now is kind of clever mixes of what we already have and different – you know, two different products in the same jug."

Added to this doubt in the feasibility of new herbicides is a recognition that weeds can develop resistance to herbicides and management is the key to stopping the development of weed resistance.

> **MN1:**

Participant: “And it’s like – it’s – you saw it 10, 15 years ago with this herbicide, what’s going to make glyphosate any different? What’s going to make Pursuit any different? What’s going to make any of them any different? They’re all going to do the same thing eventually.”

IA4:
Participant: “Well I think the introduction of Dicamba beans, that’s not solving the problem. That’s just pushing the problem down the road. Because Mother Nature is going to – if you use the same chemistry repeatedly, Mother Nature’s going to figure out a way to make something grow. So we’re not solving the problem, we’re just pushing it down the road.”

This is also related to the issue of scale that farmers identified. Large farms are noted as a necessity that requires chemical weed management – however growers also recognize that good stewardship of herbicides on such large farms is very difficult. They therefore pin their hopes on the continued development of new herbicides to replace those lost to poor management. However, as shown above, some are beginning to express doubts in this techno-optimistic system.

For some of our focus group participants, this situation resulted in despair – but more often they clung to the as-if trust that new herbicides will be developed as an explanation for their continued use of herbicide-based weed management. Rarely, some participants also mentioned solutions related to IWM such as chemical management combined with cover crops, row spacing, planting densities, and seed destruction. As one grower in Iowa saw it,

IA2:
Participant: “I think in this struggle, battle against herbicide-resistant weeds of all types, I mean it seems like people will try and go the chemical route at first, because that’s going to be the simplest, easiest, cheapest short-term way to go about it. But like, as Bill mentioned, that’s not going to solve the problem. It’s going to – everything’s going to be on the table…cover crops, you mentioned technology, in different rotations, everything’s going to be on the table in order to combat this.”

Whether an integrated management system is adopted by farmers to combat herbicide resistant weeds remains to be seen – likely it will depend at least in part on trends in farm size and whether a new herbicide does come on the market. In any case, there is evidence that some farmers in our focus groups are challenging the techno-optimism frame as it decreases in resonance. It's centrality to the majority of our discussions, though, makes it clear that techno-optimism is in no immediate threat of going into abeyance – it is a central tool for explaining and making meaning of farmers' as-if trust in herbicides as the answer to herbicide resistance.

DISCUSSION

Seeking to explain why farmers maintain faith in herbicides and tend not to adopt IWM systems, even when they understand processes of resistance, I uncovered several trends. The focus groups revealed prognostic and diagnostic elements of a techno-optimism master frame that farmers employ to explain their trust in herbicide development and continued use of herbicidal weed management. The prognostic element centered on a faith in herbicide technology as the solution to resistance problems that herbicides themselves have created. In order to maintain this faith, growers diagnosed the herbicide resistance problem not as a failure of the herbicides, but rather as a failure of farmers to manage herbicides well on increasingly large scale operations. However, there are also some challenges to the techno-optimism frame. This provides evidence that farmers' trust in herbicides and chemical companies is actually an as-if trust adopted due to the situation of dependency in which farmers find themselves.

Part of the evidence for a techno-optimism master frame comes from how farmers experience its resonance with the current sociotechnical imaginary of US agriculture. Through alignment with the sociotechnical imaginary, the techno-optimism master frame is made relevant to farmers as it is amplified to bear upon the particular issue of herbicide resistance in a conventional agriculture setting. As previously discussed, the current sociotechnical imaginary of US agriculture revolves around increasing productivity and self-sufficiency through technological innovation (Tomlinson 2013; Wilson 2001). Following this, the techno-optimism frame is amplified and aligned with the sociotechnical imaginary through clarification that the frame can be applied to promote herbicide technologies as a solution to herbicide resistance while these same technologies are excused of the blame of causing weed resistance. This resonance provides the techno-optimism master frame with narrative fidelity, in that it is consistent with larger beliefs and ideologies of US agriculture that promote technological solutions. Farmers in our focus groups are finding resonance in this master frame; this is evident from their prognosis and diagnosis of herbicide resistance in farm fields.

Farmers' faith in herbicide solutions for weed resistance had two primary components as identified in our focus groups; the faith in herbicides themselves and trust in the development of new herbicides by chemical companies. In order to make meaning of this trust in and use of herbicides, farmers drew on a prognostic dimension of the techno-optimism master frame that also resonates in regards to their experiential commensurability. Specifically, farmers' personal experiences with herbicide development match the claims of the master frame that technology is the solution to a given problem. In the past, new herbicides *have* been developed and released to address the resistance issues of previous formulations. In addition, these herbicides have generally worked well and provided adequate weed control. That this is unlikely to continue does not resonate well with farmers' experiences. Therefore farmers' prognosis – the 'what is to be done about this issue?' – draws on a techno-optimism framing to prescribe technological innovation and the continuous development of herbicide solutions. This enables their continued use of herbicides for weed control – even if some weed species develop resistance to the herbicide, the techno-optimism master frame suggests a new one can and will be developed to replace it.

As Entman (1993) points out, frames are defined not only by what they include but also by what they omit. A techno-optimism frame effectively omits the possibility that technology is the root cause of a problem, simultaneously affirming the idea that technology can cope with and even fix any emergent issues. Therefore while farmers in our focus groups recognized that over use of an herbicide can result in weed resistance, they shift the blame for resistance onto *misuse* of herbicides as opposed to the technology itself. This diagnosis enables the feasibility of a prognosis in which herbicides are seen as the solution to the problem for which they are, in fact, responsible. In this way farmers maintain a narrative fidelity in which the master frame of techno-optimism aligns with the socio-technical imaginary in US agriculture – espousing that management rather than technological innovation is the problem. Additionally, although the massive size of farms does receive some of the blame for making weed management difficult, farmers also believe these farm sizes are necessary to both make a living and feed the world. Therefore some poor management is unavoidable – however going back to the prognostic frame, the resulting herbicide resistance can be dealt with through the development of new herbicides.

The preceding techno-optimistic framing of herbicide resistance appears to indicate that farmers trust herbicides and the pesticide industry. However, there is also evidence that farmers feel trapped in a structural bind wherein there is a forced dependence on herbicides and the industry that supplies them. As mentioned throughout the discussions, farm sizes have grown to the point where cultural and mechanical weed control practices, such as cultivation and hand pulling, are not considered feasible by most farmers. Yet such large scale farms are necessary for farmers to make a living and, in their view, feed the world. In addition to this structurally binding situation, the sociotechnical imaginary of US agriculture locks farmers into an idealized future of large scale productivity supported by chemical inputs.

This dependent situation, in which farmers feel that they have no choice but to adhere to a productivity imaginary and use herbicides to manage large farms, sets farmers up for what Wynne (1992;1996) describes as an as-if trust. This type of trust appears genuine on the surface, but masks a deeper mistrust. Farmers continue to make statements of trust, however, due to their awareness of their own dependency and lack of agency – they have *no choice* but to trust expert systems (e.g. Carolan 2006). This causes anxiety and a search for evidence to support their obligatory trust (Wynne 1996) – support that a techno-optimism master frame supplies. With its prognosis of technological fixes and diagnosis based on user error, this master frame enables farmers' continuation and explanation of their as-if trust in herbicides and the chemical industry. However, there are some minor challenges being levied at the techno-optimism master frame and the trust that it enables.

Within our focus groups, statements of trust in herbicides and the chemical industry were definitely the norm. However, as shown in the results section, some growers were beginning to express doubt in the feasibility of herbicides as a long-term solution. Whether through experience with the development of resistant weed species to other herbicides or through education, they were recognizing that without proper herbicide management, weeds will eventually develop resistance. Therefore the development of new herbicides is not a solution but rather a stalling tactic that will eventually fail when no new modes of action remain to be discovered – a point it appears we may have reached. In rare instances, some growers even promoted integrated weed management as a possible future necessity. These sentiments were relatively infrequent – therefore it is extremely unlikely that the techno-optimism master frame is going into abeyance. However they are evidence of some nascent frame dissonance; farmers' knowledge and experience of herbicide resistant weeds is challenging the experimental commensurability and narrative fidelity that are fundamental to frame resonance. Still, these are mere pinpricks of a challenge; the vast majority of our respondents drew from the techno-optimism master frame to continue explaining their reliance on herbicides and trust in the chemical industry.

CONCLUSIONS

In questioning why farmers express trust in and reliance on herbicides to combat weed resistance even though they understand the benefits of IWM (Binimelis et al. 2009; Johnson et al. 2009; Webster and Sosnoskie 2010), I gathered evidence that this trust is actually an 'as-if' trust that farmers express due to their situation of dependence. In essence, farmers aren't adopting IWM because they have been convinced that IWM is not feasible by the sociotechnical imaginary of agriculture and the structural necessities of surviving in a conventional agriculture system. Rather, herbicides are seen as the only realistic choice. This produces statements of trust that are not active in nature, but rather disguise feelings of dependency and a lack of agency.

Searching for evidence to validate their obligatory trust and continued reliance on herbicides, growers in our focus groups drew on a techno-optimism master frame that they aligned with the goals and ideals of the US agriculture sociotechnical imaginary. This master frame resonated well with growers due to its narrative fidelity with the sociotechnical imaginary, as well as their experiential commensurability with its claims. This helps explain other studies (i.e. Bonny 2016; Dentzman et al. 2016; Llewellyn et al. 2004) which have found that farmers tend to have high faith in herbicide management plans, but see a decrease in this faith when they experience herbicide resistance on their own farm.

Growers in our focus groups applied the techno-optimism master frame in two ways; prognostic and diagnostic. The prognostic dimension was drawn upon to express faith that technology – in this case herbicides – would prevail and provide a solution to the problem of herbicide resistance. Even when faced with the fact that no new herbicides have been developed in the last 20 years (Boerboom and Owen 2006; Johnson et al. 2009; Norsworthy et al. 2012), respondents maintained that chemical companies were simply not trying hard enough and something would eventually be found. In order to further align with this prognosis, participants in our focus groups shifted the diagnosis for herbicide resistance away from herbicides themselves and onto misuse of herbicides. They held that 'bad' farmers and large farm sizes encouraged the overuse, rate cutting, and lack of attention responsible for herbicide resistance. While this is certainly part of why herbicide resistance has occurred, participants tended to neglect the parallel cause – the very nature of herbicides and weed biology. There were a few exceptions, however, wherein growers doubted the possibility of relying on herbicides long-term and expressed that an IWM plan may become necessary. This indicates some emerging frame dissonance – as the time since any new herbicide lengthens and farmers experience more and more resistance problems, their experiential commensurability with a techno-optimism master frame begins to fade. It is possible that we are seeing the beginnings of such a process.

It should be noted that focus groups are not generalizable, and the participants in this study tended to be relatively well-informed and innovative farmers. While this is certainly a limitation, it is also telling that even these farmers, who we might expect to be the most aware of the benefits of IWM and the dangers of herbicide reliance, draw on a techno-optimism frame to validate their use of herbicides and lack of IWM adoption. Thus this trend may be even more evident with less innovative growers. However, our participants' challenging of the frame, although important, may be a characteristic of their status as relatively well-informed and not extend as well to the general farming population. This emphasizes the need for further studies of diverse farmers from different areas to determine whether these frames are consistent across groups.

Given that farmers feel trapped in an herbicide management plan, they need to be presented with alternatives that feel feasible to them. Through processes of extension events, field days, and other forms of education, frame dissonance can be nurtured and alternatives to an obligatory trust in herbicides proffered. The less farmers feel trapped in an herbicide management plan, the more likely they are to question their as-if trust and begin acknowledging feelings of frame dissonance. Although techno-optimism seems unlikely to go into abeyance due to its strong narrative fidelity with the sociotechnical imaginary of US agriculture, it is possible that this master frame could be used to encourage IWM practices. If IWM is presented as a technological innovation capable of preserving the effectiveness of herbicides, it is more likely to be accepted than if it is framed as a movement away from technological solutions. Fostering farmers' techno-optimistic diagnosis of the cause of herbicide resistance – i.e. poor management – may also be useful if IWM can be framed as good management while herbicide-only management is framed as poor. In this way the diagnosis framing that farmers already employ can be used to encourage an alteration in their prognosis framing – herbicides may be *part* of the answer, but proper management through IWM technology is also necessary.

APPENDIX

Table 4. Demographics of Focus Group Participants by State

	Minnesota	Iowa	North Carolina	Arkansas
Number of Focus Groups	2	4	2	2
Number of Participants	16	25	11	12
Males	16	23	11	12
Age	32 - 68	33 - 77	44 - 79	24 - 73
White	16	25	8	11
Acres Managed	200 - 6,200	110 - 6,000	0 - 1,600	2,200 - 9,200
Acres Owned	0 - 2,600	0 - 1,500	0 - 900	40 - 2,200
Farms with Partner	12	18	5	10
Grows Corn	16	25	8	9
Grows Soybeans	16	25	10	12

Table 5. Techno-Optimism Master Frame Elements

	Main Theme	Sub-Themes
Prognostic Framing	New herbicides will be the solution to weed resistance	Spray herbicides more frequently
		Rotate what herbicides are used year-to-year
		Rotate what herbicides are used field-by-field
		Mix multiple herbicides in one application
		Fall back on older chemicals; attempt to have some herbicides deregulated
		Use full suggested rate of herbicide
		Use pre-emergent and residual herbicides
		Stall until new herbicides are developed
		New herbicides will be developed as long as companies try hard enough
		Hand-pulling, cover crops, and tillage can be used as a last resort
Diagnostic Framing	Mismanagement of herbicides encouraged by large farm sizes and is to blame for herbicide resistance	Farm sizes require the use of herbicides
		Large farms are harder to manage well - results in the oversimplification of weed management
		Overuse of the same herbicide year after year, especially by 'bad' farmers
		Applying a lower rate of the herbicide than is suggested (cutting rates)
		Applying herbicides when the weed is too big /poor timing
		Herbicide resistance has been self-induced by farmers
Challenging the Frame	Herbicides might **not** be the long-term solution	It's possible that no new herbicide modes of action exist to be discovered
		New herbicides aren't solving the problem, just pushing it down the road
		The resistance problem is only going to get worse
		Weeds can develop resistance to any herbicide, especially if farmers overuse a particular herbicide
		False hope/mistrust in new herbicides
		Integrated management practices may become necessary

CHAPTER 2

Herbicide Resistant Weeds as Place Disruption:
Their Impact on Farmers' Attachment, Interpretations, and Weed Management Strategies

INTRODUCTION

In conventional agricultural systems reliant on synthetic inputs, herbicides, along with herbicide-tolerant corn and soybean varieties, have dominated US agriculture as the primary method of weed control (Livingston et al. 2015). Ideal for conventional agriculture, such herbicide technologies enable the simplified and timely killing of weeds on large farms that would otherwise rely on multiple herbicides and timings for weed control. Herbicide-tolerant crops are therefore an example of a technology that enables capitalist agricultural expansion. One specific example is glyphosate, sold by Monsanto under the brand name 'Roundup', which is used to control weeds on 93 percent of soybean and 85 percent of corn acres in the US (Livingston et al. 2015). Glyphosate has been popular with US farmers due to its effectiveness in killing grasses and broadleaf plants, simplicity of use on large acreage, and having low health risks and environmental hazards compared to other herbicides (Bullock and Nitsi 2001; Hammond, Luschei, Boerboom and Nowak 2006; Gusta, Smyth, Belcher, Phillips and Castle 2011; Livingston et al. 2015).

Unfortunately, the use of herbicide-tolerant crops, along with promotion by Monsanto, has led to some unintended consequences. The overuse of glyphosate, as necessitated by capitalist agricultural demands and economies of scale, has resulted in the development of herbicide resistant (HR) weeds as a product of natural selection (Bonny 2016; Livingston et al. 2015). This result is not surprising given the history of weeds developing resistance to herbicides that are used repeatedly over time. In fact, the US has 155 weed species resistant to various herbicides, and 16 resistant to glyphosate in particular (Heap 2016). This resistance presents a very serious problem for farmers, as it results in crop yield loss due to weed competition, reduced commodity prices, lower land values, and increased costs due to alternative or additional methods of weed control (Norsworthy et al. 2012). This is especially problematic where resistance levels are high – for instance in Georgia where the presence of glyphosate-resistant Palmer amaranth has increased management costs in cotton by $48/ha (Norsworthy et al. 2012).

While academic extension educators recommend the use of integrated weed management (IWM) practices to lessen the development and impact of resistant weeds, such practices have seen relatively little adoption (Llewellyn, Lindner, Pannell and Powles 2004; Webster and Sosnoskie 2010). Rather, the majority of farmers continue to rely on current and hoped-for future herbicides (Bonny 2016; Livingston et al. 2015; Norsworthy et al. 2012). Reasons for this include the increased complexity and time involved in applying IWM, which requires the combination of various preventative, mechanical, cultural, chemical, and biological weed management techniques to delay herbicide resistance (Barman et al. 2014; Harker 2013). However, there may be additional reasons for adopting or foregoing IWM; several studies have found that farmers tend not to adopt IWM *unless* they have experienced herbicide resistance *on their own farm* (Bonny 2016; Livingston et al. 2015; Llewellyn, Lindner, Pannell and Powles 2004). This observation is particularly relevant given that herbicide resistance problems are not uniform across the US.

As demonstrated by the increased weed management costs in Georgia, particularly severe infestations of herbicide resistant weeds occur in the Southern US (Heap 2016; Inman et al. 2016; Livingston et al. 2015; Norsworthy et al. 2012). This pattern is due in part to the climactic character of the South, which in tandem with socio-economic expectations encourages continuous mono-cropping and allows weed populations to thrive (Ervin and Jussaume 2014).

Building on this geographical distribution of herbicide resistant weeds, I work from the belief that increased presence of herbicide resistant weeds in the Southern US can be viewed as a form of place disruption (Altman and Low 1992; Manzo and Devine-Wright 2014) that triggers farmer's attachment to their farm and influences their weed management behaviors. This helps explain why farmers do not adopt IWM until they have resistance issues on their own farm.

In this chapter, I explore a range of place attachment dimensions to help understand the processes of attachment that farmers are going through when they experience place disruption in the form of herbicide resistance. In clarifying this relationship, I hope to discover whether HR weed disruption increases place attachment, and if so whether it has a positive or negative influence on a) farmers' interpretation of HR weeds and b) actual weed management behaviors. This literature will clarify how farmers' reaction to actual or threatened herbicide resistant weeds relates to place-specific factors such as attachment.

Specifically, I plan to test the various place attachment dimensions that have been proposed by others to determine how US corn and soybean farmers experience place attachment. Although farmers may already experience place attachment, I look at how instances of place disruption in the form of herbicide resistant weeds may trigger *stronger* feelings of attachment to their farm and community. I will be using exploratory factor analysis to test the relevance of a variety of place dimensions proposed by Stokols and Shumaker (1981), Proshansky (1978) Raymond, Brown and Weber (2010), Ardoin, Schuh and Gould (2012) and Scannell and Gifford (2010b). These include place dependence, place identity, environmental attachment, environmental identity, family bonding, community bonding, and economic dependence.

Following this, I will use path analysis to analyze the utility of two place attachment frameworks in describing how farmers' place attachment influences their herbicide resistant weed management behaviors. The frameworks that I will be testing are 1) the direct effect model (Stedman 2003) and 2) the disruption framework (Mihaylov and Perkins 2014). The direct effect model is a simplistic base model in which physical dimensions of place directly affect residents' place attachment. Building on this model, the disruption framework incorporates social networking to explain people's intentions and behaviors towards a physical place disruption.

I begin by reviewing literature on the concept of place to situate my discussion in the context of place theory. Following this, I discuss dimensions of place attachment before exploring how it relates to conservation and agriculture. Finally, I conclude my theoretical review with a focus on place disruption studies – exploring how they relate to place attachment and may have relevance to the problem of herbicide resistant weeds in the US. Next I describe the methods used to collect and analyze my data, followed by results, a discussion, and conclusions.

LITERATURE REVIEW

The scholars credited with the birth of place studies are two geographers, Tuan (1975; 1977) and Relph (1976). In addition these forerunners, scholars from psychology, natural resource sciences, and sociology have been active in developing the current place scholarship (Trentelman 2009). Given the variety of disciplines that place scholarship draws from, there is some inherent messiness in its definitions and themes. Indeed it has been variously defined as centers of meaning constructed by experience, attitudes, intentions, and purposes (Relph 1976; Tuan 1977); centers of consumption (Urry 1995); a radically open category combining the real and imagined (Soja 1996); a process that has no single identity (Massey 1991); and "…space filled up by people, practices, objects, and representations" (Gieryn 2000 p. 465). The only thing that seems to be agreed upon is that place is fundamentally different from space in that it is granted some form of meaning by groups or individuals – although how this meaning is defined and who can give place meaning is debated (e.g. Gieryn 2000; Massey 1991; Soja 1996). Meaning then appears as a unifying theme of the place literature.

In addition to definitional differences, place has been contested on the grounds of its basic dimensions. Gieryn (2000), in his seminal chapter on place in sociology, provides a list based on an extensive literature review, identifying three primary features of place. The first is geographic location – place is a unique spot in the universe that allows us to define here versus there. The second is material form. This constitutes the physicality of place – it is things and objects in a particular spot. Third is the investment of meaning and value. This is perhaps the most universally accepted quality of place, as it applies to differing conceptualizations including cyber places that have no physical form (Milligan 1998). When people experience places as real they are real in their consequences (e.g. Tickamyer 2000). Again, a unifying factor here is that place is a site of meaning – regardless of whether or not that site is virtual or physical. How this meaning is attached to agricultural spaces and how it influences farmers' weed management behaviors is central to the focus of this chapter.

PLACE ATTACHMENT

The development of the concept of place attachment is credited to Tuan (1977), who described it as a subconscious affective relationship with place that develops through long-term interaction and/or intensity of experience (Trentelman 2009; Tuan 1977). A more contemporary definition comes from Gieryn (2000) who defines place attachment as the formation of emotional and sentimental bonds between people and places resulting from accumulated biographical experience, length of residence, community sentiment, culturally shared meaning, and geography. Similarly, Altman and Low (1992) describe place attachment as an integrative concept involving attachments, place, different actors, different social relationships, various scales, and temporal aspects. Both Altman and Low (1992) and Gieryn (2000) emphasize how people define and potentially become attached to specific places based on shared cultural meanings created by societies, making place attachment a fundamentally sociological concept.

There is a history of both qualitative and quantitative work associated with place attachment, with a predominant focus on creating measures and identifying its constituent parts (Trentelman 2009). What these parts are, however, is still a topic of some debate and confusion stemming from different lenses employed by the multiple disciplines involved in place attachment research (Ardoin, Shuh and Gould 2012). For instance, environmental psychologists have historically divided place attachment into two constituent parts; place dependence and place identity (Trentelman 2009). Place dependence evaluates the utility of a place for people's needs and wants compared to other places (Stokols and Shumaker 1981; Trentelman 2009) while place identity refers to how people feel that a place is part of them (Proshansky 1978; Trentelman 2009). Research such as that by Williams and Vaske (2003) has supported the differentiation of place dependence and identity, finding that using both increases validity compared to using a one-dimensional measure of place attachment. However, in more recent studies, additional dimensions of place attachment have been put forth for testing.

Proposing four dimensions of place attachment, Ardoin, Schuh and Gould (2012) used structural equation modeling and confirmatory factor analysis to identify biophysical, sociocultural, psychological, and political economic place attachment dimensions. Raymond, Brown, and Weber (2010) also investigated four different dimensions of place attachment – place identity, place dependence, nature bonding, and social bonding. They found that place identity is the strongest predictor of place attachment, and that social bonding was a better predictor when broken into family bonding (weaker) and friend bonding (stronger). Place attachment has also been proposed to separate around social and natural environment dimensions (Beckley 2003; Brehm, Eisenhauer and Krannich 2006) and have a distinct economic dependence component (Cross, Keske, Lacy, Hoag and Bastian 2011). Even when basic dimensions are agreed upon, they are often labeled in different ways – for instance Scannell and Gifford (2010b) break place attachment into natural and civic dimensions while Larson, De Freitas and Hicks (2013) refer to environmental, social and economic dimensions. The primary components of these definitions are the same, but become divided and specified in different ways through the use of different terminology.

Obviously there is some confusion over the dimensions of place attachment. Despite this, there is a general agreement that place attachment can be defined as an affective relation to place, and that this relationship can come about given time and/or intensity of interactions

(Trentelman 2009; Tuan 1975). Additionally, social and natural aspects of place attachment seem to have been generally accepted across studies. However, beyond these factors there is minimal overlap. We must question what a unifying framework of place attachment dimensions might look like, or if one is even necessary in the first place. It may be better to allow for some messiness in the literature as long as each researcher clearly identifies and define their dimensions (Trentelman 2009). Additionally, there are those who have advocated *against* dividing place attachment into multiple dimensions, instead arguing that it is a fundamentally holistic concept that should not be broken into parts (e.g. Williams and Stewart 1998). This parallels calls to treat society and the environment as an inseparable conjoint constitution of elements, as opposed to considering each factor alone (Freudenburg, Frickel and Gramling 1995).

PLACE ATTACHMENT, THE ENVIRONMENT, AND AGRICULTURE

One issue associated with the definitional confusion and preponderance of dimensions proposed for place attachment is disparate findings regarding the *effects* of place attachment. This has been especially characteristic of research on how place attachment affects environmental management and activism. In several studies, place attachment increased support specifically for pro-environmental actions. Although IWM could be considered 'pro-environmental', it is more of a strict management act for farmers. Still, consideration of studies looking at pro-environmental behavior does give us an idea of how place attachment and people's interaction with the environment are connected. For instance, Brehm *et al*. (2006) found that strong environmental attachment predicted peoples' support for protecting open spaces in the US Intermountain West, while Vaske and Kobrin (2001)'s study in Colorado similarly found that place identity increased general and specific environmental behaviors.

Devine-Wright (2009) also found that place attachment promotes community participation and engagement in place-protective action.

Although there are many examples of how place attachment increases pro-environmental management, there are examples of the reverse as well. Caston Broto et al. (2010) found that place attachment in a polluted town in Bosnia had various effects. On the one hand, strong place attachment combined with a strong belief in the danger of pollution led to community activism. However, place attachment combined with disbelief in the danger of pollution led to viewing the coal plant as an opportunity for economic growth. Another study displaying this complexity is by Vorkinn and Riese (2001). They looked at place attachment and attitudes towards a proposed hydropower plant in Norway, finding that while strong attachment to natural areas predicted negative attitudes towards the plant, strong municipality attachment increased support. Finally, Uzzel, Pol, and Badenas (2002) studied two villages in England, finding strong place attachment in both. However, one village translated this attachment into pro-environmental behavior while one translated it into negative environmental behaviors. These studies emphasize that place attachment can have disparate effects on environmental behaviors and attitudes.

Scannell and Gifford (2010b) attempted to clear up some of this confusion. They found that natural but not civic place attachment predicts pro-environmental behaviors, and recognize that this contrasts with Uzzell et al.'s 2002 study. They therefore theorize that place attachment predicts behaviors that are congruent with the dominant values of the group a person identifies with (Scannell and Gifford 2010b). This may help to explain differing results in terms of how place attachment impacts conservation behavior.

Place attachment has also been studied in relation to farmers' management practices on their farm. Researchers hypothesized a close relationship between people who work intimately on their land and a stronger connection to its biophysical elements (Beckley 2003). Gosling and Williams (2010) found that place attachment predicted environmentally friendly behavior *intentions*, but not actual behavior on farms. Unfortunately, they did not define their measure of place attachment – therefore it is unclear whether it was describing social attachment, natural attachment, or some other dimension. This is particularly relevant given that Lincoln and Ardoin (2015) found that sense of place and related attachment were *very* strong predictors of farmer's sustainable practices in South Kona, Hawaii. Similarly, Marshall, Park, Adger, Brown, and Howden (2012) in their study of Australian peanut farmers' willingness to undergo transformational change conclude that "…for change events that do not involve moving locations, place attachment is likely to be a positive influence on adaptation; place attachment brings resources such as networks, social capital, local knowledge and a sense of well-being into a region" (p. 7). Taking this literature as a whole, we see that place attachment has been found to increase pro-environmental intentions and occasionally behaviors of farmers. However, given the limited number of studies and the disparate nature of more general findings on place attachment and environmental behaviors, these findings need further testing. Specifically, I build on this literature by looking at how herbicide resistant weeds may effect farmers' place attachment, and how that attachment influences farmers' weed management practices. This breaks away from the more common focus on how attachment impacts farmers' pro-environmental management behaviors, instead looking at management behaviors that have more to do with profit and longevity of their farm as well as considering the impact of a place disruption in the form of HR weeds.

PLACE DISRUPTION

Place disruption is characterized by changes to a place that threaten place distinctiveness, self-efficacy, positive distinctiveness, control, and continuity (Anton and Lawrence 2016; Devine-Wright 2009). These disruptions are theorized to trigger a greater sense of place attachment, dependence, and identity given that the threat of losing a place makes these affects extant (Anton and Lawrence 2014). Disruptions specifically refer to negative changes such as environmental disasters, which may disorient residents in terms of navigation (both natural and manmade community reference points) and psychology (disruption of experiences of home, place and identity) (Silver and Grek-Martin 2015). Some research extends to positive changes as well, emphasizing how *quality* and *rapidity* of perceived changes impact place attachment, not the changes in and of themselves (von Wirth, Gret-Regamey, Moser and Stauffacher 2016). What may be perceived as a disruption to one group – i.e. they perceive a place change negatively – may not be perceived as a disruption to another group – i.e. they could perceive it as neutral or even positive.

Common empirical applications of the place disruption concept focus on disruptions in the form of natural disasters. Anton and Lawrence (2014) and Paton, Burgelt and Prior (2008) apply a disruption framework to understand preparedness for bushfires in Australia. Both found that living in an area at high bushfire risk increased place dependence – and that in turn place attachment predicted participation in community preparedness measures. Similarly, studying wildfire preparedness in the US, Bihari and Ryan (2012) found that high levels of place attachment predicted participation in local wildfire prevention associations and other preparedness measures.

Flood preparedness is another natural disaster studied as a place disruption. De Dominicis et al. (2015) studied preventative behaviors in two Italian cities – one moderately at risk for flooding and one at high risk. They found that in low risk contexts risk perceptions directly affect preventative behaviors. In high risk contexts, however, risk perceptions were high but *negatively* moderated by place attachment to decrease preventative behaviors. In these high risk contexts, *less* attached people are *more* likely to engage in preventative measures. De Dominicis et al. (2015) theorize that in this case choosing not to act on the flooding risk serves as a protective mental shield to defend one's place and social identity from the perceived threat. This aligns with Mihaylov and Perkins' (2014) assessment that "Those most attached to a place might accept and rationalize an inevitable disruption, in accord with cognitive dissonance theory, while those least attached welcome any change" (p. 67). In contrast, Mishra, Mazumdar and Suar (2010) found that flood preparedness in India was increased by economic dependence on place and genealogical attachment to ancestral lands.

In general, place disruption appears to increase the intention to prepare for a disaster and *sometimes* actual preparedness behaviors. Place attachment may also increase community response to disasters that have already happened; i.e. rebuilding after a tornado (Silver and Grek-Martin 2015). However, there are exceptions in which disruption interacts with high attachment to produce avoidance and lessen preparedness (De Dominicis, Fornara, Cancellieri, Twigger-Ross and Bonaiuto 2015). My goal is to extend this research to the socio-environmental problem of herbicide resistant weeds – an environmental and social disruption co-created by humans and nature. Specifically, I investigate the *perceived* threat of HR weeds and the *actual* geographical threat of HR weeds, focusing on how these disruptions impact attachment and how this may condition reactive and preventative management behaviors.

The disruption framework described in the preceding section is the put forth by Mihaylov and Perkins (2014). This framework builds on Devine-Wright's five stages of psychological responses to place change. These are: 1) become aware that place change is imminent, 2) interpret implications, 3) evaluate change as positive or negative, 4) decide how to cope/respond and 5) decide what can be done and act. Mihaylov and Perkins adapt this model to create a schematic that can be used in structural equation modeling (Appendix A). This schematic proposes that environmental disruption, place definition, various place attachment dimensions, and belief in collective efficacy all impact interpretive processes, i.e. step two in Devine-Wright's framework. These interpretive processes iteratively influence place-based social interactions and bridging social capital, as well as having a unidirectional impact on citizen participation and community response to the disruption, i.e. steps 3 and 4 in Devine-Wright's framework. Additionally, interpretive processes are moderated by social interactions and citizen participation to impact community responses – the final step in the framework. This model helps account for differing responses to place disruptions and effects of attachment as seen in the literature. Using my own data on US corn and soybean farmers' place attachment, herbicide resistance problems, and management practices I test the utility of this model for describing farmers' reaction to herbicide resistant weeds as a place disruption.

SUMMARY

The literatures on place and attachment converge on the focus of place meanings and how these impact attitudes and behaviors. When related to agriculture, place attachment influences both behavioral intentions and actual behaviors. This may be particularly relevant to US corn and soybean farmers as place-disruptive herbicide resistant weeds bring feelings of place attachment to the forefront. This leads me to my main research question; 'Do herbicide resistant weeds act as a disruption to farmers' place attachment, and how does this process impact farmers' concern and behaviors related to herbicide resistant weed management?'

Based on my literature review, I assume that farmers' beliefs and practices regarding herbicide resistant weeds result in part from an empirical place attachment formed through interactions with biophysical elements of their farm and social relationships in their families and communities, which can be impacted by place disruption in the form of herbicide resistant weeds. I will be testing farmers' place attachment dimensions, specifically drawing on proposed dimensions identified by Stokols and Shumaker (1981), Proshansky (1978) Raymond, Brown and Weber (2010), Ardoin, Schuh and Gould (2012) and Scannell and Gifford (2010b). I also test two frameworks from the place attachment literature; 1) the direct effect model (Stedman 2003), 2) the disruption framework (Mihaylov and Perkins 2014).

I have four initial questions I will investigate for this chapter. They are; *1*) Can farmers' place attachment can be broken into biophysical, community, identity, dependence, and family dimensions? *2*) How does the presence of place-disruptive herbicide resistant weeds impact farmers' place attachment?, *3*) Do dimensions of farmers' place attachment impact their interpretation and management of herbicide resistant weeds?, and *4*) How will models of place attachment perform in relation to herbicide resistance management?

METHODS

Although the need for a place-based analysis was identified during focus group analysis (see Dentzman, Gunderson and Jussaume 2016), the primary data for this paper comes from a survey of place attachment and weed management practices. The focus groups were conducted in spring 2015 with corn and soybean farmers in Iowa, Minnesota, North Carolina, and Arkansas, with the goal of understanding how farmers think about herbicide resistant weeds and their management. During data analysis, it became apparent that focus groups in different regions had significant differences in weed management practices –we suspected that this was due to biophysical place factors such as HR weed prevalence and partially due to community factors such as a local Zero Tolerance Program. A strong desire to stay in farming and keep a specific parcel of farmland in the family also appeared to influence decision-making. As place was not a primary questioning route in these focus groups, there was not enough data to fully analyze these trends. However, relevant place-based questions were subsequently incorporated into a larger survey.

INSTRUMENT DEVELOPMENT PHASE

Following the focus group coding and analysis, I, along with input from the rest of the research team, developed a survey based on the themes and ideas uncovered in the focus groups. Given that spatial differences surfaced between the focus groups, we suspected a place-based effect to be pertinent. Therefore we drew from our focus group findings to use the place-relevant language and concerns of the farmers within the survey itself. As Creswell (2014) points out, it is difficult to develop survey items from focus group analysis. For this reason, we conducted cognitive interviews of the survey to clarify that the questioning route was clear and true to the focus group themes. Farmers who were willing to take the survey in front of a team member and give their feedback were recruited either directly by a research team member or by extension educators the team was familiar with. The feedback given by these individuals was invaluable in refining the survey themes and wording to make sure the questions were measuring the intended constructs.

SURVEY PHASE

A survey based on the focus group results was sent to 9,000 corn and soybean farmers across the US in winter of 2015 and spring of 2016 – with 839 returning usable. This gives us a response rate of 9.3 percent – just below the national average farmer response rate of about 10-20% (Pennings, Irwin and Good 2002). This was, largely, a result of our chosen sampling frame. We used a marketing company that maintains a list of farmer mailing and email addresses – specifically those farmers who subscribe to certain agricultural mailing lists. Unfortunately, it appears that this list was not maintained to remove individuals who were no longer farming. Evidence of this comes from the numerous calls we received stating that the intended survey recipient had died, retired, moved on from farming, etc. Fortunately, those surveys that were returned were nearly all complete – there was very little measurement error. This is an indication that our survey instrument was appropriate for the population, despite the fact that we had difficulty reaching said population. The validity of our instrument is further confirmed by comparison with the 2012 Iowa Farm and Rural Life Poll. When comparing similarly phrased questions about herbicide resistance, our survey showed an extremely similar distribution of responses to those in the Iowa Farm and Rural Life Poll. This indicates high reliability of these questions and validity of our instrument.

The survey included a question set based on an analysis of place attachment dimensions drawn from studies by Stokols and Shumaker (1981), Proshansky (1978) Raymond, Brown and

Weber (2010), Ardoin, Schuh and Gould (2012) and Scannell and Gifford (2010), along with pertinent information from the focus groups, such as the importance of a farm being passed down among generations. Included were items to measure place identity, place dependence, environmental attachment, economic dependence, community attachment, family bonding, and non-attachment. To see this question with its original wording, see Appendix F.

PROPOSED ANALYSIS

I use two primary types of data analysis for this chapter. First, I use exploratory factor analysis (EFA) to identify dimensions of place attachment that are relevant to farmers. The purpose of EFA is to determine which variables cluster together, indicating representation of a larger underlying construct (DeVellis 2012). This is particularly useful for measuring variables that are not directly observable, such as place attachment, and has been advocated and used extensively in this literature (e.g. Ardoin et al. 2012; Gross and Brown 2008; Hallak, Brown and Lindsay 2012; Hidalgo 2013; Jorgenson and Stedman 2001; Manzo and Devine-Wright 2014; Ramkissoon, Graham Smith and Weiler 2013). I use EFA to test the place attachment literature's long list of possible place dimensions, determining where the clusters are for this particular corn and soybean farming population. Together, these dimensions cover place identity, place dependence, environmental attachment, economic dependence, community attachment, family bonding, and several reverse-worded measures of 'non-attachment'. Using EFA, I am able to determine if these dimensions are separable – that is, how many factors they load onto. For example, if all the variables intended to measure some aspect of environmental attachment cluster together, they are considered to load onto the same latent variable – environmental attachment. This enables me to separate out potentially relevant place attachment dimensions for the farmers in my sample.

Following this identification of place attachment dimensions, I employ path analysis to test Mihaylov and Perkins' (2014) disruption model. This model posits that a biophysical place disruption interacts with 1) place attachment and 2) belief in community efficacy to influence an individual's interpretation of the disruption. These interpretations then influence whether the individual participates in neighboring/citizen actions as well as their behaviors to directly mitigate the disruption. These behaviors constitute the outcome variable 'weed management practices'. For a visual outline of this model, see Appendix A.

In my model, I use the presence of HR Palmer amaranth on a farmer's farm as my disruption variable. Although we asked about a variety of herbicide resistant weeds on farmers' land, Palmer amaranth constitutes one of the most common, disruptive and feared herbicide resistant weeds to date (Egan 2014; Inman et al. 2016; Webster and Sosnoskie 2010). It has been shown to increase farm management costs by up to 58% (Webster and Sosnoskie 2010), can produce up to 1 million seeds per plant, is highly competitive, and can significantly decrease yield (Inman et al. 2016). Therefore Palmer amaranth was chosen to represent larger herbicide resistance problems that are affecting the US – it is a cultural touchstone representing the true and alarming potential of herbicide resistance. It should also be noted that farmers' reported their own belief that HR Palmer amaranth was infesting their land – we do not have data to tell whether the weeds they are experiencing are *actually* herbicide resistant.

My collective efficacy and neighboring participation variables were constructed as latent variables from several measurement variables (See Appendices C and F). Additionally, I had five latent 'interpretation' variables. These were identified using factor analysis and include a spread interpretation, incentive interpretation, management interpretation, new technology interpretation, and a concern interpretation. A spread interpretation indicates that respondents think HR weeds are a serious problem that is highly mobile and easily transferable from farm to farm and region to region. An incentive interpretation indicates that respondents think HR weeds can be adequately addressed through financial incentives for farmers to control their weeds. A management interpretation indicates that the respondent believes modern farming practices are at least partly at fault for the development and spread of HR weeds, and therefore will need to change to provide a solution. A new technology interpretation indicates that the respondent believes that new technological innovations, especially new herbicide modes of action, will solve resistance problems. Finally, a concern interpretation indicates that the respondent sees HR weeds as an extremely serious agricultural issue. My outcome variables are based on common definitions of basic and complex herbicide and IWM practices in the literature. The outcome variables are thus defined in a four-cell typography of intensity of basic herbicide use, integrated herbicide use, basic IWM practices, and complex IWM practices. Four disruption models were analyzed – one for each of the four outcome variables.

RESULTS

DESCRIPTIVE STATISTICS AND LATENT VARIABLES

I obtained 839 responses from the survey of US corn and soybean growers conducted in spring of 2016. Respondents were distributed across 28 states, with 41 percent coming from Arkansas, Iowa, Illinois, Minnesota, Nebraska and Texas. For a detailed overview of descriptive statistics for the variables used in each of my models, see Appendix A. It should be especially noted that based on t-tests my sample is skewed compared to USDA data in several respects. Firstly, my average farm size is significantly larger than the average farm size of 449 acres reported by the USDA. My sample also over represents farmers that have been on the same farm for 10+ years and those making over $50,000 per year. Women farmers are extremely underrepresented. Therefore my sample can be considered more male, more geographically stable, and richer in both land and income than the average farmer surveyed by the USDA.

In order to test which dimensions of place attachment are relevant to farmers, I ran an exploratory factor analysis using the variables described in Appendix F. The analysis itself appears in Appendix C. Variables are considered to indicate an underlying latent variable when a) they theoretically apply b) relatively strong factor loadings cluster together on a particular variable and c) factor loadings are greater than 0.30 (DeVellis 2012). In my analysis of place attachment variables, two primary factors were identified. The first is composed of the place attachment dimensions 'farm identity', 'farm family bonding', 'farm environment identity' 'farm job identity', and 'farm dependence'. These variables had factor loadings ranging from 0.50 to 0.70. I term this factor 'holistic farm attachment', as the variables involved represent a holistic way of being attached to the farm – farmers in my sample do not appear to differentiate between their attachment to their farm environment, farming identity, farm family, and dependence on their farm. The second factor is composed of the dimensions ‘community ties’, ‘NOT attached to farm’, and ‘discuss farming with neighbors’. The factor loadings range from 0.41 to 0.51. I term this factor ‘community attachment’, as it represents farmers who are *not* particularly attached to their farm but *are* closely involved in and attached to their community.

The average rating for holistic place attachment, as measured on a 3-point scale, was 2.42. For community place attachment, the average score was 2.01. This indicates a very high level of holistic place attachment among farmers, as well as a medium level of community attachment. This is not surprising given results in the literature describing consistently high scores on place attachment scales (Manzo and Devine-Wright 2014), as well as the fact that my sample was slightly skewed towards farmers who had been on the same farm for a longer period of time – place attachment is generally considered to increase with the length of residence in a particular place (Beckley 2003; Lincoln and Ardoin 2015; Manzo and Devine-Wright 2014).

In addition to my latent measures of place attachment, I performed factor analyses for several other latent variables in my model. These were ‘collective efficacy’, ‘neighboring/citizen participation’, all five of my interpretation variables, and all four of my outcome ‘weed management’ variables. All of these had factor loadings of greater than 0.30 on all dimensions. For the specific results of these analyses, please see Appendix C.

DIRECT EFFECTS MODEL FINDINGS

According to the direct effects models (Appendix D), the presence of herbicide resistant Palmer amaranth on their farm increased farmers’ community attachment by 0.13 points on a 3-point scale. A similar effect was seen for holistic farm attachment – having HR Palmer amaranth on their farm increased this by 0.08. With a CFI of 0.80 and an RMSEA of 0.08, this model provides a good fit. Indeed, all of the direct effect models had fit statistics within 0.01 points of these values. This supports the theory that HR Palmer amaranth acts as a place-disruption factor triggering stronger place attachment, both in community and holistic forms. Additionally, community attachment and holistic attachment increased basic IWM usage (by 0.33 and 0.23 on a 3-point scale respectively). Only holistic attachment, however, had an impact on complex IWM usage, increasing it by 0.17. Neither form of attachment had any impact on basic or integrated herbicide use.

Looking at the control variables, there are several significant effects worth exploring. First of all, the likelihood of having HR Palmer amaranth on-farm was increased by managing larger acreage, having a greater proportion of rented to owned acreage, and being located in the Southern US. Community attachment was increased by being in the South, but decreased with increasing age of respondent. Holistic attachment was also decreased by increasing age. In addition to these impacts, the controls had some effects on farmers' weed control practices. Although basic IWM use was not impacted by any of the controls, complex IWM use was increased by being in the South. Basic and integrated herbicide use were both increased with increasing acres managed and decreased with increasing age.

Next, the direct effect models were run with a change in the predictor variable. In this iteration, the model was run *only* for respondents who did *not* have HR Palmer amaranth on their farm. Rather, I used the intensity level of HR Palmer amaranth in the respondents' states to determine if this also triggered higher place attachment. Theoretically the threat of HR Palmer amaranth in a farmer's state, even if it is not yet on their farm, could act as a *potential* or *imagined* future disruption. Our model shows, however, that farming in a state with high intensity of HR Palmer infestation did *not* influence community or holistic attachment. Our model therefore shows that for place attachment to be activated, farmers must be aware of HR

Palmer amaranth at a closer scale than the state. Therefore, although being in the South increased state HR Palmer amaranth intensity by 1.50 on a 5-point scale, this did not directly impact farmers' place attachment. Rather, being in the South makes it more likely that a farmer will have HR Palmer amaranth *on their own farm*, and this is what results in higher holistic and community attachment.

DISRUPTION MODEL FINDINGS

The disruption models that I tested (see Appendix D) were all within 0.01 of a 0.80 CFI score and a 0.04 RMSEA score, indicating a good fit. Additionally, the AIC score was more than twice that of the direct-effects models, indicating that the disruption models are a better overall fit. In disruption models, the physical place disruption, in this case having HR Palmer amaranth on one's farm, is posited to impact place attachment and collective efficacy. My findings bear this out – having HR Palmer amaranth on one's farm increased community attachment by 0.14 and holistic attachment by 0.08. These results are similar to those found in the direct effects model. Having HR Palmer amaranth on-farm also *decreased* respondents' belief in collective efficacy by -0.08 units.

According to the disruption model, holistic farm attachment has an impact on a few different forms of interpretation at the center of the model. I included five types of possible interpretations, and holistic farm attachment had a significant impact on three of these five. In the positive, holistic attachment increased a concern interpretation (0.07) and a spread interpretation (0.14). In the negative, holistic attachment decreased an incentive interpretation (-0.21).

Community attachment, being another form of place attachment, is theorized in the disruption model to influence the same five interpretations as holistic attachment. However, it only affects two – and only one of those is the same interpretation that holistic attachment impacts. This shared impact is an increase in concern interpretation (0.04 for community attachment). Community attachment also increases a new technology interpretation (0.10).

Collective efficacy is also posited in the disruption model to affect the five interpretations. It has significance in *all* of these relationships – and all of them are negative. Belief in collective efficacy, therefore, decreases an incentive interpretation (-2.21), a management interpretation (-0.98), a concern interpretation (-.031), a new technology interpretation (-0.45) and a spread interpretation (-0.90). The five interpretations themselves are seen in the disruption model to impact neighboring/citizen participation as well as actual behaviors. In this model, only management interpretation and concern interpretations affected neighboring/citizen participation. A management interpretation had a negative impact (-0.15), while a concern interpretation had a strong positive impact (1.10).

Looking at how the five interpretations influenced actual management practices, we must look at each of the four outcome variables (basic herbicide use, integrated herbicide use, basic IWM, and complex IWM) by itself. Basic herbicide use was impacted by just one interpretation – a new technology interpretation. This increased the intensity of basic herbicide use by 0.13 on a 3-point scale. Integrated herbicide use was not impacted by *any* interpretation. Neither simple IWM use nor complex IWM use were impacted by any of the interpretations. However, *both* simple and complex IWM use were increased by neighbor/citizen participation. Therefore, we begin to see a chain of direct and indirect effects.

In the first case – with basic herbicide use as the outcome variable – the intensity of herbicide use was predicted by farmer's interpretation that new technology would come along to solve herbicide resistance problems. This interpretation was positively impacted by community attachment and negatively by collective efficacy. In turn, community attachment was increased by the presence of HR Palmer amaranth on-farm while belief in collective efficacy was decreased. Thus having HR Palmer on-farm impacts basic herbicide use in two ways. First, it increases community attachment, which increases a new technology interpretation and therefore makes farmers more likely to use high intensity herbicide management. Secondly, it decreases belief in collective efficacy, which decreases a new technology interpretation and therefore makes farmers less likely to use high intensity herbicide management. Put another way, high community attachment and high belief in collective efficacy *increase* farmer's interpretation that a new technology will come along to solve the HR weed problem, prompting them to continue use of basic herbicide control methods on much of their farmland. Therefore, having HR Palmer amaranth on-farm *indirectly increases* basic herbicide use through community attachment and *indirectly decreases* basic herbicide use through collective efficacy beliefs.

In the second case – with simple and complex IWM use as the outcome variables – the intensity of IWM practices was not predicted by any of the five interpretations, but *was* predicted by farmer's level of neighboring/citizen participation. Having HR Palmer amaranth on one's farm increased holistic and community place attachments, which promoted a concern interpretation. This concern in turn increased neighboring/citizen participation which predicted farmers using IWM practices on a larger portion of their farm. Having HR Palmer amaranth on one's farm also decreased belief in collective efficacy – while collective efficacy itself decreased a concern interpretation. This means that having HR Palmer amaranth decreases farmer's belief that the community can solve the problem, in turn having the paradoxical effect of decreasing their concern and lessening their neighboring/citizen participation. This, in turn, means less complex IWM usage. Therefore, having HR Palmer amaranth indirectly impacts simple and complex IWM management practices positively through place attachment and negatively through disbelief in collective efficacy.

In terms of control variables, there are several impacts that are consistent throughout the models. Having HR Palmer amaranth on one's farm was increased by being in the South, having a higher proportion of rented acres, and managing more acres. Community attachment was increased by being in the South and decreased with a rise in age. Holistic attachment also decreased with a rise in age. Citizen participation was increased by being in the South, increased with increasing proportion of acres rented, decreased with increasing years on the current farm, and decreased with increasing age. Basic herbicide use intensity was increased by having more acres and decreased with increasing age. Integrated herbicide use was likewise increased by managing more acres and decreased with increasing age, although gender had no impact. Neither simple nor complex IWM usage were significantly affected by any of the controls. Finally, an incentive interpretation was decreased with increasing years on the current farm.

In addition to running the disruption model with on-farm HR Palmer amaranth as the 'disruption', I also ran this model for farmers who did *not* have this weed on their farm. In these cases, the 'disruption' variable was the level of HR Palmer amaranth intensity in a respondent's home state. Similar to the direct effects model, state-level HR Palmer amaranth intensity had no significant impact on holistic or community attachment. It also did not influence belief in collective efficacy. Therefore, it had no impact on farmer's interpretations or actual weed management practices.

DISCUSSION

In this chapter, I had four main questions that I attempted to answer. Using the results above, I will assess the outcome of each of these questions. First, I discuss whether farmer's place attachment can be broken into different dimensions, followed by whether HR weeds constitute a place disruption that influences farmers' place attachment. Next, I address whether farmers' place attachment affects their interpretation of herbicide resistant weeds and related management practices. Finally, I address the performance of the direct effect and disruption models I tested.

The first question I investigated was whether farmers' place attachment can be broken into different dimensions. I tested this using an EFA of place identity, place dependence, environmental attachment, economic dependence, community attachment, and family bonding dimensions from the literature. I found that, for my sample, place attachment did not break into these dimensions. Rather, place attachment divided into a holistic farm-based place attachment and a non-farm community attachment. This supports a holistic view of place attachment in which it cannot be divided into dimensions (e.g. Williams and Stewart 1998). It also hints that, for farmers at least, place and community attachment may be considered distinctive kinds of attachment similar to how Trentelman (2009) divides them and encourages considering them as distinct. This is not to discount the literature from which I drew the different dimensions of place attachment. Rather, it indicates that for my sample of US corn and soybean farmers, their place identity, dependence, farmland, job, and family legacy are so tied to place that it is impossible to consider them independently. This fits with Beckley's (2003) assertion that farmers have a particularly strong place attachment due to being so actively involved with their land. Farmers that are less attached to their farmland also seem to be more attached to their local community.

Secondly, I asked whether the presence of herbicide resistant weeds constitutes a disruption to place that triggers farmers' place attachment. Specifically, I investigated whether HR Palmer amaranth on a farmers' land influenced their holistic place attachment and community attachment. This was confirmed, with this weed triggering increased feelings of both types of attachment. Given that HR Palmer significantly threatens farmers' livelihood and ability to keep their farm, it is no surprise that it causes a significant disruption and triggers latent feelings of attachment. However, the *threat* of herbicide resistance does not appear to have the same effect. I tested how farmers *without* herbicide resistant Palmer amaranth on their farm were impacted by the threat of this weed given its intensity in their state. However, even a very high intensity of HR Palmer amaranth infestation in a state was not enough to trigger farmers' feelings of either holistic farm attachment or community attachment. This indicates that, although it may be of concern, state-level herbicide resistance alone is not enough of a threat to trigger place attachment. This supports findings by Bonny (2016) and Llewellyn et al. (2004) that farmers tend to adopt IWM practices only after herbicide resistance appears on their own farms.

Next, I tested whether dimensions of farmers' place attachment influence their interpretation of herbicide resistance and through these interpretations their weed management behaviors. I found that holistic farm attachment and community attachment influenced various interpretations – although not all of them. Specifically, holistic farm attachment increased a concern interpretation and a spread interpretation. It also acted to decrease an incentive interpretation. Therefore being highly attached to their farm and related identity caused farmers to interpret herbicide resistance as a serious concern that is likely to spread, while decreasing their belief that financial incentives would be sufficient to deal with herbicide resistance.

Community attachment also increased a concern interpretation, while additionally increasing a new technology interpretation. We see that farmers with a high level of community attachment interpret herbicide resistance as a serious concern, but also believe that new technological innovations will be enough to combat it. It is significant that community attachment increases the interpretation of technological fixes, whereas holistic farm attachment does not. Given that my community attachment variable was associated with farmers being *unattached* to their farmland, this indicates that being attached to their farm causes farmers to think more about what they perceive *won't* work to combat herbicide resistance (i.e. financial incentives), while being attached to the community causes them to think more about what they perceive *will* work (i.e. technological fixes). This may be a situation in which farmers who *are not* attached to their specific farm think technology is the larger picture answer. It may not work on their farm if it is already heavily infested with HR weeds, but the farming community at large may be seen as standing to benefit from new herbicide technologies to combat herbicide resistant weeds.

A couple interpretations also affected farmers' actual weed management behaviors, although not all. For one, farmers' basic herbicide use – that is, the intensity of their pre- and post-herbicide use - is increased by an interpretation that new technologies would solve current herbicide resistance problems. This technology interpretation is, as mentioned, increased by community attachment. Therefore a higher community attachment that results as a consequence of HR weeds on a farm encourages farmers to believe in technological solutions and rely on basic herbicide weed management.

Integrated herbicide use, simple IWM, and complex IWM were not impacted by any of the five interpretations. However, both simple and complex IWM use *were* increased by an increasing level of farmers' neighboring behaviors (i.e. discussing and getting weed management information from neighboring growers). This emphasizes how community-level conversations are extremely important for encouraging farmers to use basic and increasingly involved integrated weed management solutions to herbicide resistance. Additionally, neighboring practices were increased with an increasing concern interpretation. This concern was, in turn, heightened by high holistic farm attachment and community attachment. As we have already seen, the presence of HR Palmer Amaranth on a farmers' land triggers concern. Thus this place disruption triggers two kinds of attachment, increasing a concern interpretation that encourages farmers to be more interactive with neighboring farmers. This then encourages them to take on more IWM practices.

It should also be noted that farmers' belief in collective efficacy – that is, farmers' thinking that cooperative and community-led programs can help solve herbicide resistance problems – has several impacts. This collective efficacy decreased when farmers have HR Palmer Amaranth on their land. It in turn decreases every kind of interpretation in my model. This is particularly important in that it decreases both a new technology interpretation and neighboring/citizen participation. These interpretations respectively increase basic herbicide use and simple/complex integrated management. Therefore farmers who believe that collective action can help solve herbicide resistance may use fewer basic herbicides and less integrated management – thinking that the problem can be solved collectively. This ironically results in less fewer proactive weed management solutions.

In summary, the disruption model proved to be a good fit for my data. It improved on the fit statistics from the direct effects model, and several of the posited relationships were significant. However it also emphasizes the necessity of considering a range of place attachment dimensions, interpretations, and outcomes. If only one type of weed management, for instance low IWM usage, was investigated as an outcome variable I would have concluded that place attachment has no impact on it. Similarly, studies of place disruption may want to consider several measures of disaster relief and preparedness, as these may be differentially triggered by various interpretations of the disruption.

CONCLUSIONS

For US corn and soybean farmers in my sample, place attachment revealed itself in a holistic form that was only separable from community-based attachment. This supports arguments that breaking place attachment into multiple smaller dimensions is unnecessary – or at least that it should not be done arbitrarily (Williams and Stewart 1998). Indeed, different groups of people may experience place attachment differently. It is theorized that farmers specifically have a unique bond with place given that they work closely with the land, rely on it for their livelihood, and often have a genealogical attachment to their farmland (Beckley 2003). This may encourage a more holistic form of place attachment than, for instance, that experienced by a visitor to a national park. Therefore it is important to leave the definition of place attachment open for researchers to identify in relation to their particular area of study. A common definition of the dimensions of place attachment may not be necessary or even desirable when different communities experience place attachment in different ways – some separable and some holistic.

Both holistic farm attachment and community attachment were increased by the presence of herbicide resistant Palmer amaranth on farmers' land. This indicates that herbicide resistance does constitute a place disruption that triggers latent feels of attachment. Herbicide resistant weeds are certainly a threat to farmers and their way of life – they fit the definition of a place disruption in that they threaten place distinctiveness, the self-efficacy of farmers, control over their farmland, and the continuity of their farm through future generations (Anton and Lawrence 2016; Devine-Wright 2009). Instead of responding to this threat by detaching from a place, farmers in my sample have responded through an increased recognition of their attachment to both their farm and community.

This increased attachment has several impacts on how farmers interpret herbicide resistance. These interpretations, along with neighborly communication, influence some but not all of farmers' weed management practices. More attached farmers, who are triggered to be so by HR weeds on their land, have a higher 'new technology' interpretation that leads them to use more pre- and post-herbicides. On the other hand, attachment increases concern, which increases information exchange with neighboring farmers. This information exchange then leads farmers to employ more integrated weed management strategies; supporting the idea that community based weed management is an important tool to combat herbicide resistance (e.g. Ervin and Jussaume 2014).

These findings point to several ways to help farmers move towards a more sustainable integrated weed management plan. First, it will be important to educate farmers on the likelihood of new herbicide development and new technological solutions. A new herbicide mode of action has not been discovered for over 20 years (Duke 2011; Livingston et al. 2015; Harker et al. 2012) and is not expected in the near future. Other solutions, such as crops resistant to three or more herbicides (Pates 2016), are only short-term solutions and will exacerbate the herbicide resistance problem in the end. Secondly, there needs to be a focus on increasing farmers' interactions with their neighbors and other farmers. Although my model showed that neighboring interaction aids in adopting simple and complex IWM practices, the survey also showed that nearly 45% of farmers have *never* discussed herbicide resistance with their neighbors. This is corroborated by findings from Dentzman and Jussaume (forthcoming). In their focus groups of corn and soybean growers, they found that growers were very reticent to discuss weed management with neighbors as it contrasted with their ideologies on farmers' individualism and autonomy. These findings demonstrate that farmers have some difficulty or reticence to communicate with their neighbors and other farmers about herbicide resistance – however when they do so it has serious benefits in terms of IWM usage. Programming that builds on the concern triggered by place disruption may help bring growers together for these necessary discussions.

My findings show that US corn and soybean farmers demonstrate both holistic and community forms of place attachment that are intensified by the presence of herbicide resistance on their farms, although not by the threat of herbicide resistance in their state. The triggered holistic and community attachments held by my sample were mediated by interpretation to impact neighborly action, basic herbicide use and simple/complex IWM use through a relatively long and complex chain of effects. This demonstrates the multifaceted nature of the herbicide resistance issue and how farmers make decisions about weed management practices, helping to explain why farmers sometimes do not adopt IWM practices despite knowledge of their benefits. Building on these findings, the promotion of sustainable integrated weed management practices will necessarily involve engaging farmers with processual knowledge on herbicide development chains as well as providing types of learning that build on community and place attachments.

APPENDICES

APPENDIX A

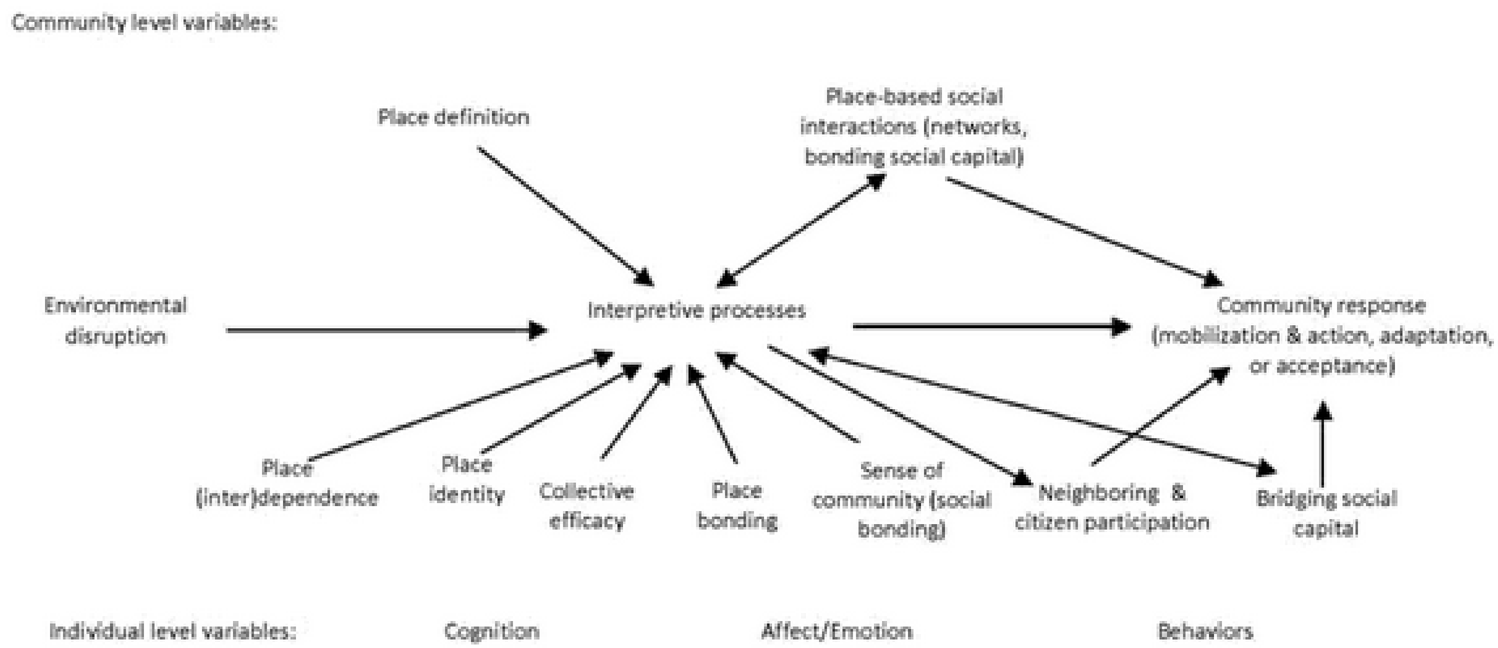

Figure 1. Mihaylov and Perkins' Disruption Framework

APPENDIX B

Table 6. Descriptive Statistics (n=674)

Variable	Measurement				
	No	Yes			
Herbicide resistant Palmer Amaranth on farm?	59.1%	41.0%			
	None	Low	Medium	High	Very high
Herbicide resistant Palmer Amaranth intensity in state	12.3%	28.6%	18.7%	19.7%	20.6%
	North	South			
Region	65.3%	34.7%			
	Mean	Std Dev			
Acres Managed (0-20,000)	1354	1619			
Acres Rented (0-8,250)	780	10.8			
Years on Current Farm (0-80)	29.5	13.7			
Age in Years	57.5	2.6			
Income	<$50,000	$50,000-99,000	$100,000-249,000	$250,000+	
	13.7%	32.8%	33.2%	20.3%	
	Male	Female			
Sex (0=Male, 1=Female)	98.5%	1.5%			
Holistic Place Attachment	Disagree	Agree	Strongly Agree		
Farm identity	4.8%	25.8%	69.4%		
Attached to farm genealogically	6.2%	19.7%	74.0%		
Identify with environment on farm	17.8%	43.2%	39.0%		
Identify with farming job	15.9%	26.7%	57.4%		

Table 6. (cont'd)

Farmland contributes to success	20.8%	46.1%	33.1%
Community Place Attachment	Disagree	Agree	Strongly Agree
Community ties	21.8%	42.0%	36.2%
Not attached to farm	61.9%	22.0%	16.2%
Discuss farming with neighbors	12.0%	47.8%	40.2%
Collective Efficacy	Disagree	Agree	
HR weeds cannot be managed without cooperation	35.5%	24.2%	
Farmer-led organization would help control HR weeds	73.4%	26.6%	
HR weeds spread due to lack of communication	91.0%	9.1%	
	Unlikely	Neither	Likely
Community action will help solve HR weed problems	27.9%	31.0%	41.1%
Incentive Interpretation	Unlikely	Neither	Likely
Government incentives will help control HR weeds	31.6%	22.1%	46.3%
Private incentives will help control HR weeds	20.3%	24.8%	54.9%
Management Interpretation	Unlikely	Somewhat Likely	Very Likely
Modern agriculture creates HR weeds	30.9%	47.6%	21.5%
New herbicides are likely to be overused in the future	38.0%	46.4%	15.6%
Weeds can evolve resistance to any new herbicide	17.1%	55.9%	27.0%
Spread Interpretation	Disagree	Agree	
Spread of HR weeds is a local concern	29.0%	71.0%	

Table 6. (cont'd)

Spread of HR weeds is a county-wide concern	28.7%	71.3%	
Spread of HR weeds is a region-wide concern	31.8%	68.2%	
Spread of HR weeds from neighbors is likely	15.8%	84.2%	
Concern Interpretation	Not Concerned	Somewhat Concerned	Very Concerned
Concerned about single-herbicide resistance	5.4%	26.0%	68.6%
Concerned about multi-herbicide resistance	13.0%	26.1%	60.9%
	No	Yes	
Changed management due to HR weed concern	11.6%	88.4%	
New Technology Interpretation	Unlikely	Somewhat Likely	Very Likely
University discovery of new technologies solve HR	26.3%	45.4%	28.3%
Discovery of new herbicide mode of action solve HR	12.8%	45.4%	41.8%
Development of new HR crops solve HR	14.4%	44.4%	41.3%
Neighboring Citizen Participation	Not Important	Somewhat Important	Very Important
Information on HR management from neighbors	22.6%	51.0%	26.4%
	No	Yes	
Discuss HR weed problems with neighbors	44.6%	55.4%	
Basic Herbicide Usage	Did not use	< 80% of fields	80%+ of fields

Table 6. (cont'd)

Uses pre-herbicides	10.2%	33.8%	55.9%
Uses post-herbicides	5.1%	27.1%	67.9%
Integrated Herbicide Usage	Did not use	< 80% of fields	80%+ of fields
Uses multiple herbicide modes of action	7.1%	38.6%	54.2%
Rotates herbicide modes of action	17.8%	50.3%	31.9%
Uses herbicide mixtures	7.6%	40.4%	52.0%
Low Integrated Weed Management	Disagree	Agree	Strongly Agree
Scouts fields	21.8%	35.8%	42.5%
Varies weed management by field	28.6%	37.3%	34.1%
	Did not use	< 80% of fields	80%+ of fields
Uses hand weeding	41.5%	36.3%	22.2%
High Integrated Weed Management	Did not use	< 80% of fields	80%+ of fields
Uses planting density to control weeds	49.4%	31.9%	18.7%
Uses cover crops	62.2%	28.5%	9.4%
Uses planting date to control weeds	59.6%	26.4%	14.0%
Uses narrow rows to control weeds	38.0%	19.7%	42.3%
Uses weed maps	83.2%	11.1%	5.6%

APPENDIX C

Table 7. Exploratory Factor Analyses

Holistic Place Attachment	Factor 1	Factor 2
Farm identity	**0.68**	-0.12
Attached to farm genealogically	**0.65**	-0.36
Identify with environment on farm	**0.65**	0.10
Identify with farming job	**0.55**	-0.21
Farm land contributes to success	**0.52**	-0.12
Community Place Attachment		
Community ties	0.61	**0.59**
Not attached to farm	-0.52	**0.52**
Discuss farming with neighbors	0.57	**0.61**

Collective Efficacy	Factor 1
HR weeds cannot be managed without cooperation between farmers	**0.57**
Farmer-led organization would help control HR weeds	**0.75**
HR weeds spread due to lack of farmer communication	**0.40**
Community action will help solve HR weed problems	**0.70**

Incentive Interpretation	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Government incentives will help control HR weeds	**0.58**	-0.29	0.33	0.33	-0.00
Private incentives will help control HR weeds	**0.58**	-0.34	0.36	0.36	0.12
Management Interpretation					
Modern agriculture creates HR weeds	-0.08	**0.53**	0.23	0.23	0.33
New herbicides are likely to be overused in the future	0.08	**0.67**	0.23	0.23	0.15
Weeds can evolve resistance to any new herbicide	-0.07	**0.40**	0.35	0.35	0.24

Table 7. (cont'd)

Spread Interpretation					
Spread of HR weeds is a local concern	-0.05	-0.10	**0.71**	0.60	-0.45
Spread of HR weeds is a county-wide concern	-0.33	-0.14	**0.74**	0.63	-0.44
Spread of HR weeds is a region-wide concern	-0.40	-0.07	**0.67**	0.52	-0.40
Spread of HR weeds from neighbors is likely	-0.11	-0.06	**0.52**	0.49	-0.31
Concern Interpretation					
Concerned about single-herbicide resistance	0.24	0.25	0.51	**0.53**	-0.13
Concerned about multi-herbicide resistance	0.26	0.24	0.51	**0.51**	-0.14
Changed management practices due to HR weed concern	0.25	0.18	0.42	**0.42**	-0.06
New Technology Interpretation					
University discovery of new technologies will solve HR problem	-0.03	-0.13	0.41	0.41	**0.53**
Discovery of new herbicide modes of action will solve HR problems	-0.23	-0.23	0.49	0.49	**0.65**
Development of new HR crops will solve HR problems	-0.24	-0.29	0.46	0.46	**0.62**

Neighboring/Citizen Participation	Factor 1
Get information on HR weed management from neighbors	**0.77**
Discuss HR weed problems with neighbors	**0.77**

APPENDIX D

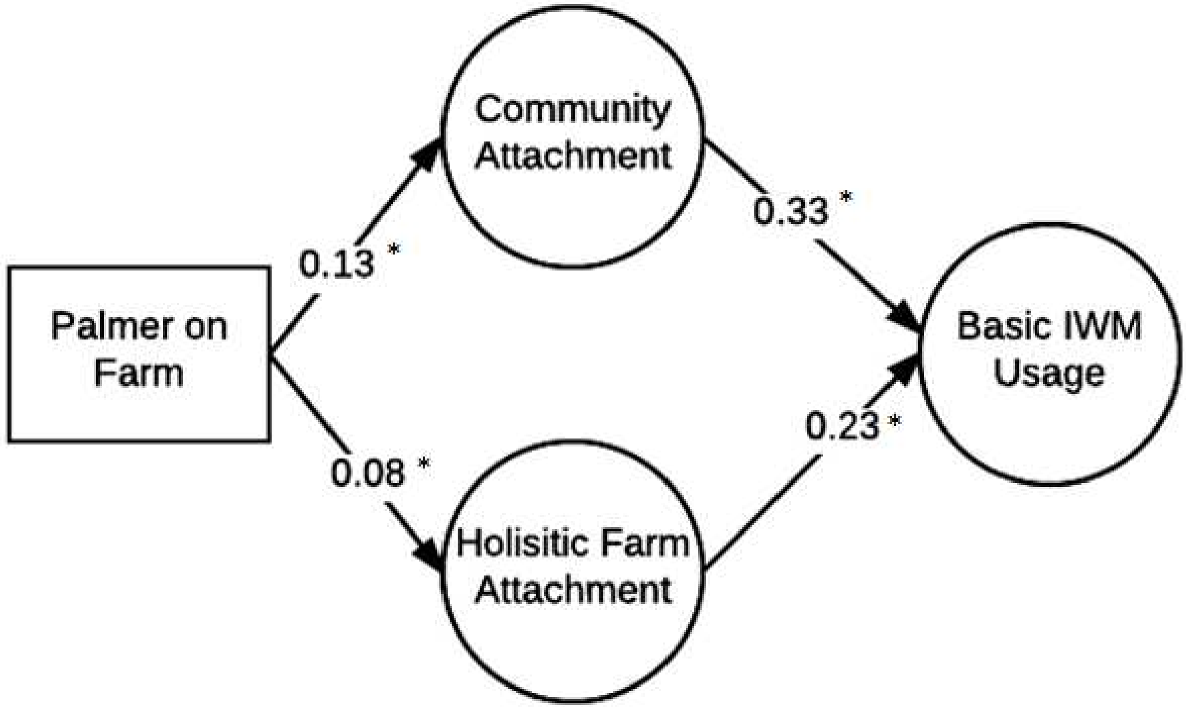

Figure 2. Direct Model for Basic IWM Usage *[*p<0.05, **p<0.00]*

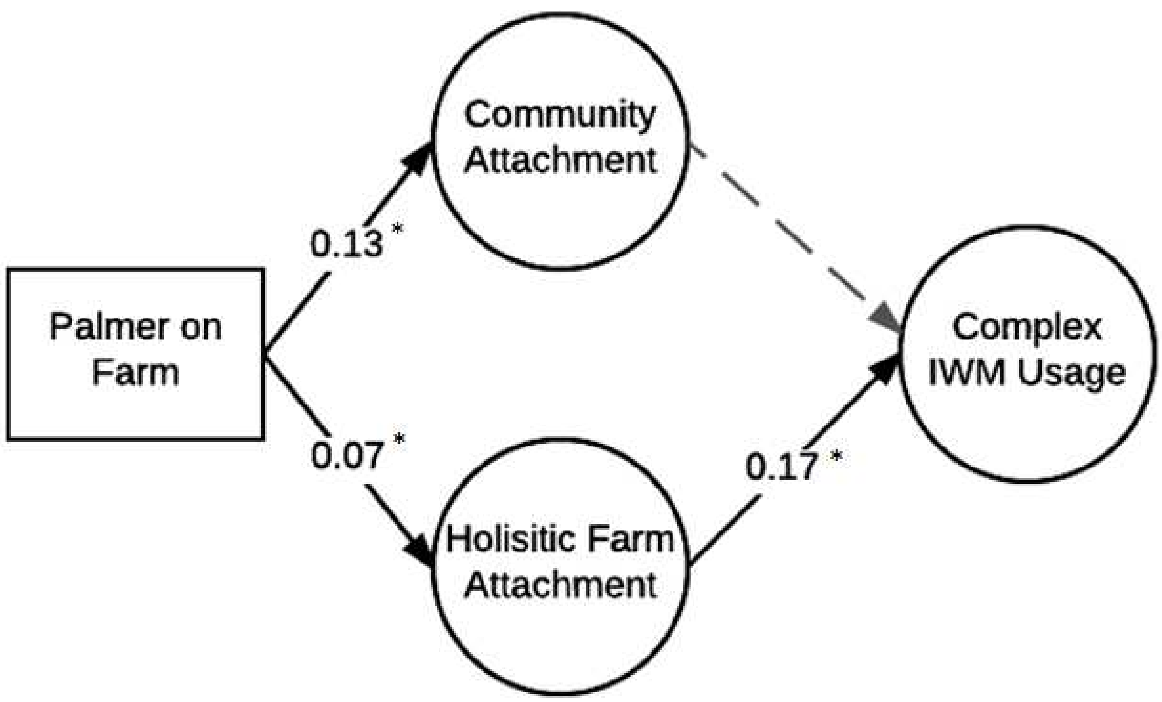

Figure 3. Direct Model for Complex IWM Usage *[*p<0.05, **p<0.00]*

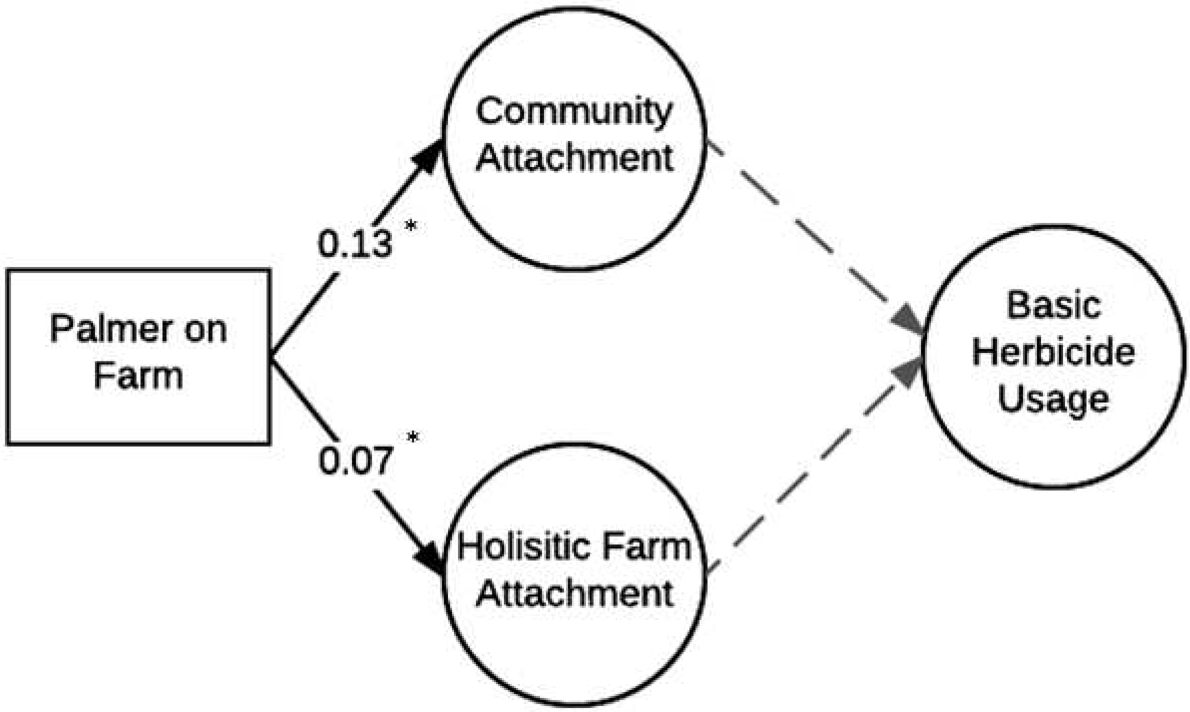

Figure 4. Direct Model for Basic Herbicide Usage *[*p<0.05, **p<0.00]*

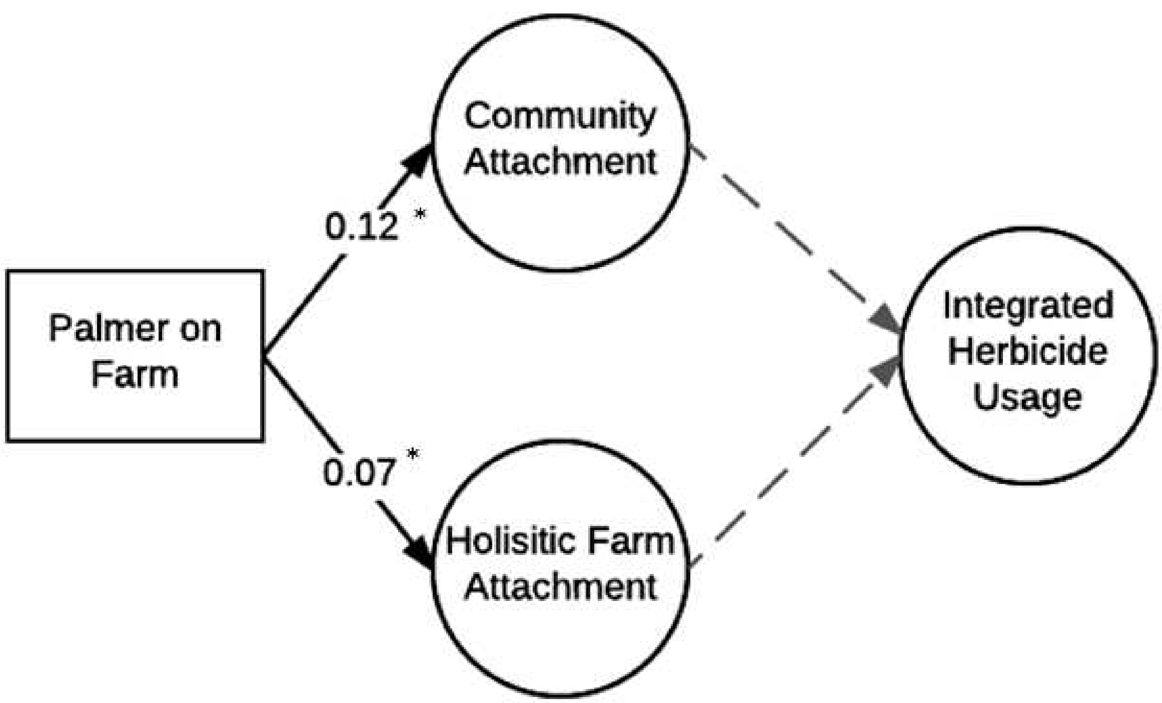

Figure 5. Direct Model for Integrated Herbicide Usage *[*p<0.05, **p<0.00]*

APPENDIX E

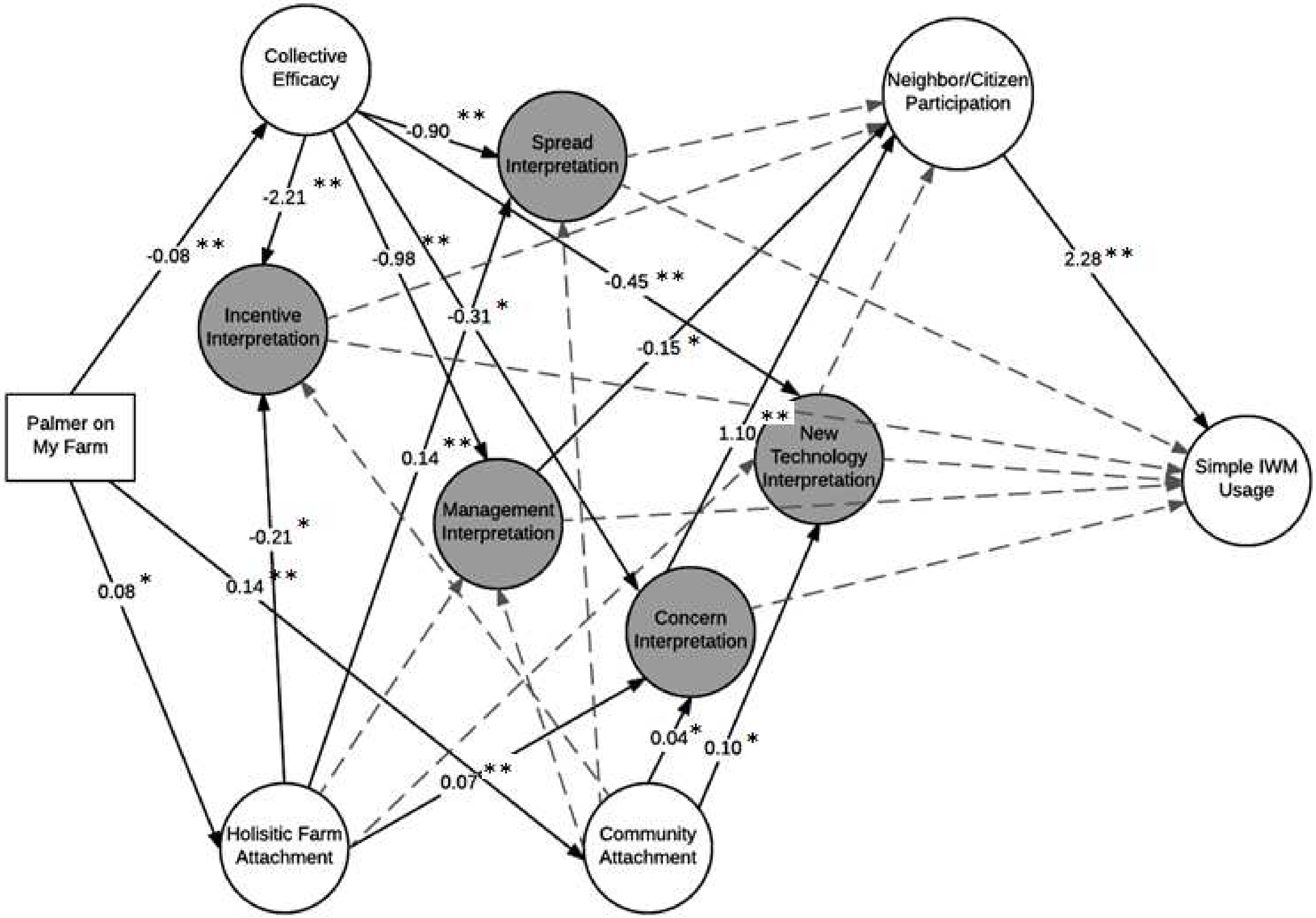

Figure 6. Disruption Model for On-Farm Palmer Impacting Simple IWM Usage *[*p<0.05, **p<0.00]*

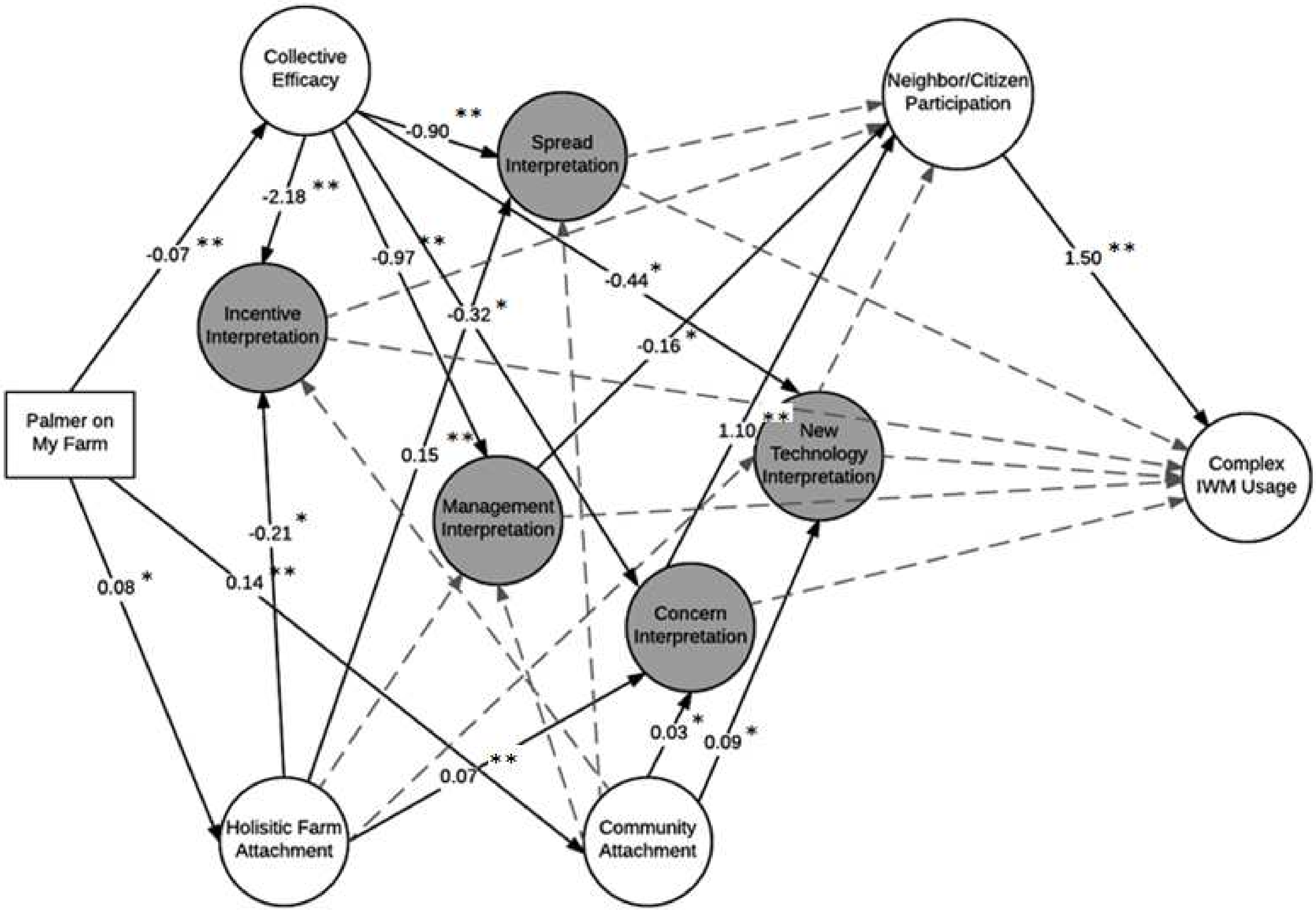

Figure 7. Disruption Model for On-Farm Palmer Impacting Complex IWM Usage *[*p<0.05, **p<0.00]*

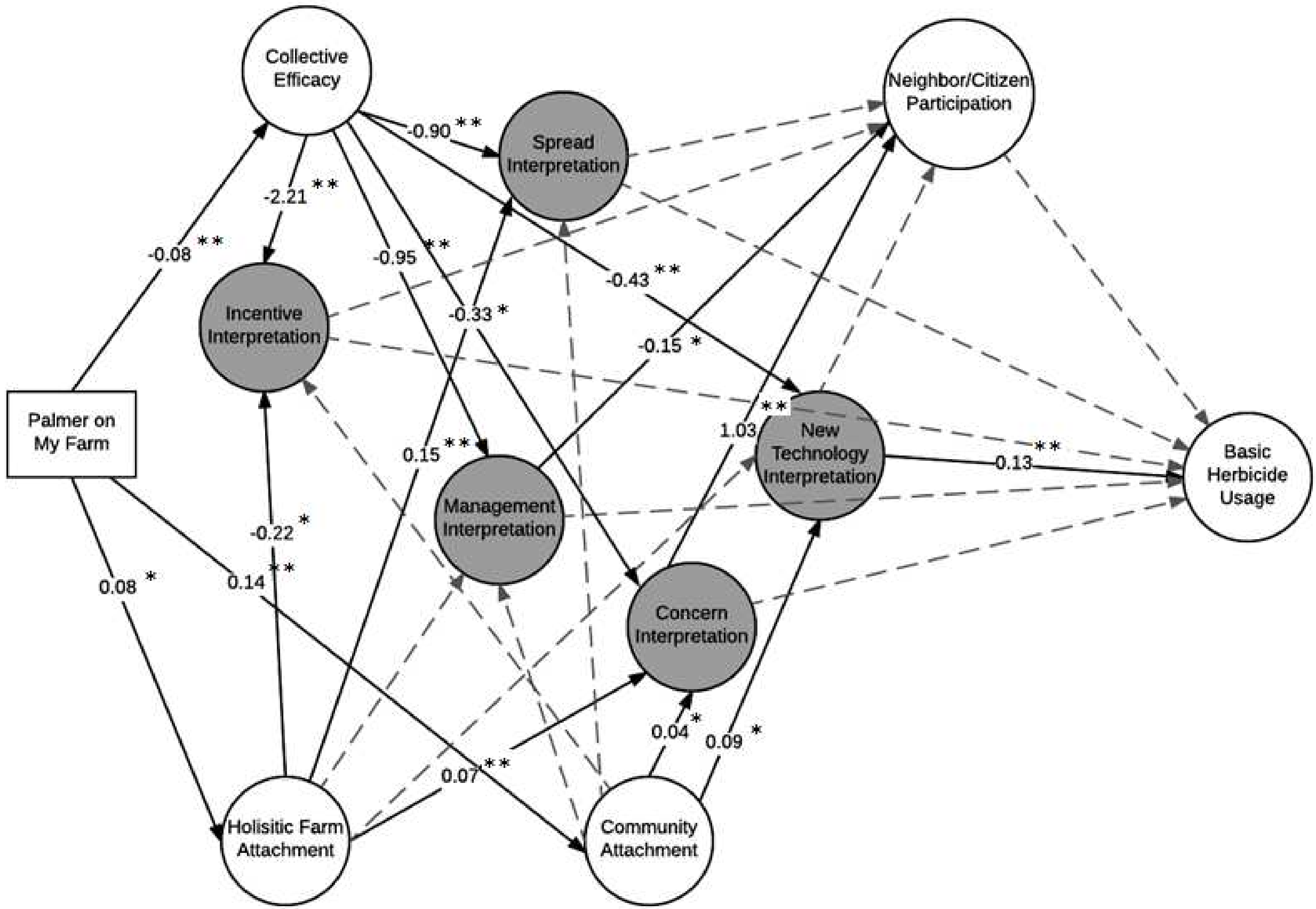

Figure 8. Disruption Model for On-Farm Palmer Impacting Basic Herbicide Usage *[*p<0.05, **p<0.00]*

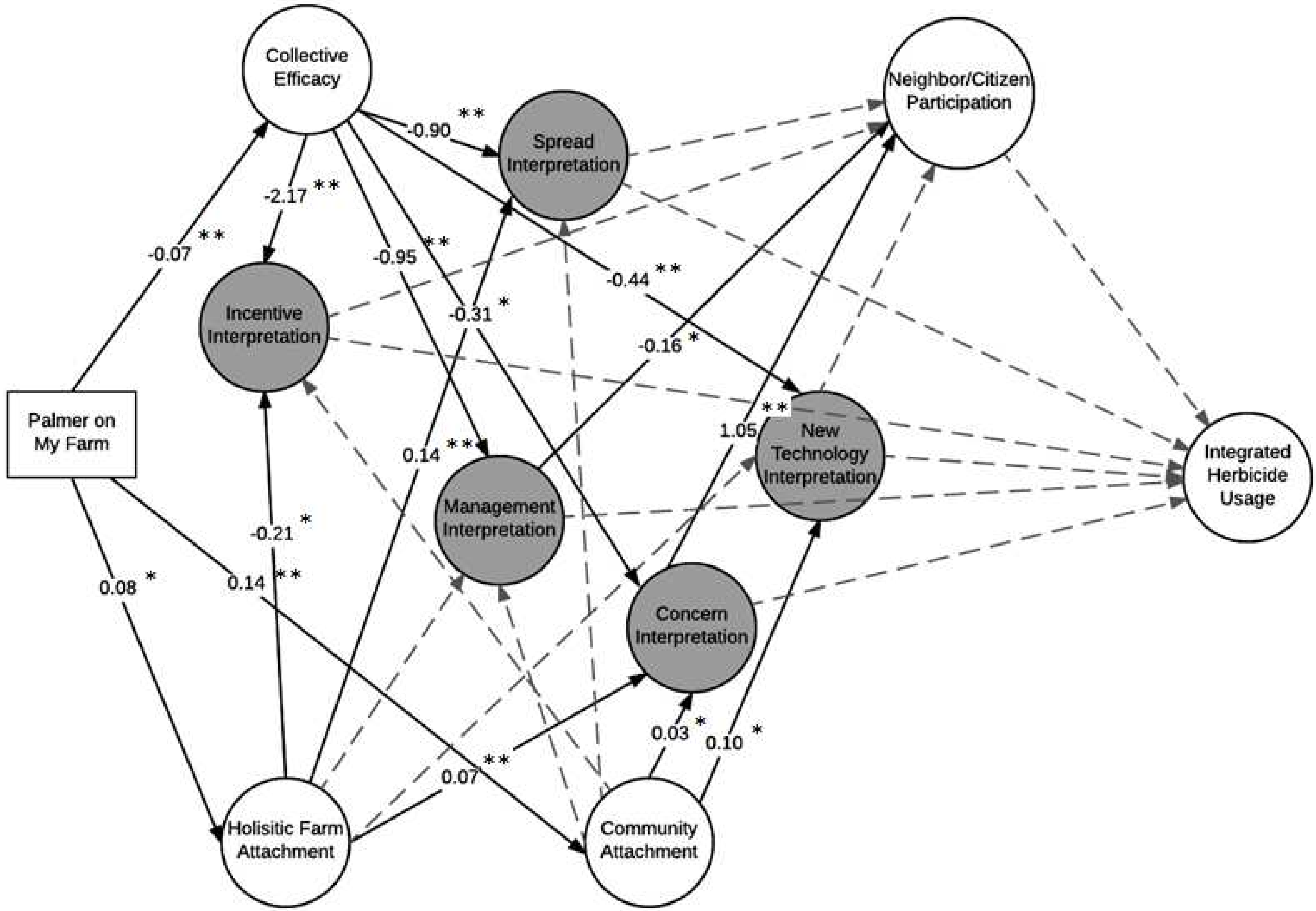

Figure 9. Disruption Model for On-Farm Palmer Impacting Integrated Herbicide Usage *[*p<0.05, **p<0.00]*

APPENDIX F

Table 8. Place Attachment Variables

Holistic Place Attachment

I consider my farm to be an important part of my identity

I am attached to my current farm land and would like to see it stay in my family

I consider the natural environment on and around my farm to be an important part of my identity

I would rather farm than have any other kind of job

The characteristics of my current farm land (soil type, topography, etc.) closely contribute to my success as a farmer

Community Place Attachment

I have strong ties to other farmers in my community

I am not particularly attached to my current farm land – I could see myself farming somewhere else

I discuss farming issues with other farmers in my community

Collective Efficacy Variables

Collective Efficacy

Weed resistance cannot be managed effectively without cooperation amongst farmers in a community

In your opinion, is it acceptable for a farmer led local organization to require farmers in the area to use an approved set of practices to manage herbicide resistant weeds?

Lack of communication between neighboring farmers contributes to the spread of herbicide resistant weeds

Privately-led community action to improve adoption of weed Best Management Practices is likely to be useful in helping manage herbicide resistant weed problems

Interpretation Variables

Incentive Interpretation

Government financial incentives to spur adoption of weed Best Management Practices is likely to be useful in helping manage herbicide resistant weed problems

Table 8. (cont'd)

Private company financial incentives to spur adoption of weed Best Management Practices is likely to be useful in helping manage herbicide resistant weed problems

Management Interpretation

Modern agricultural practices contribute to the conditions that spur evolution of herbicide resistant weeds

Any new chemical mode of action that is developed to control weeds will be overused

When new weed management technologies are introduced, it is only a matter of time before pests evolve resistance

Spread Interpretation

I am concerned about herbicide resistant weeds spreading to my farming operation from nearby farming operations

I am concerned about herbicide resistant weeds spreading to my county from nearby counties

I am concerned about herbicide resistant weeds spreading to my region of the U.S. from other regions

Even if I keep my fields clean, I could get herbicide resistant weeds from neighboring farms

Concern Interpretation

How concerned are you about the presence of weeds resistant to a single herbicide on your farming operation?

How concerned are you about the presence of weeds resistant to multiple herbicides on your farming operation?

Have you changed any of your weed management approaches on your farm as a result of concern over herbicide resistance?

New Technology Interpretation

Land grant university discovery of new weed management strategies is likely to be useful in helping manage herbicide resistant weed problems

Private company investment in the discovery of new herbicide modes of action is likely to be useful in helping manage herbicide resistant weed problems

Private company investment in the development of new herbicide tolerant crops is likely to be useful in helping manage herbicide resistant weed problems

Neighboring/Citizen Participation Variables

Neighboring/Citizen Participation

Over the past two years, information from other growers was important for developing weed management approaches for your farming operation

Have you ever discussed with the owner/manager of a field abutting or near one of yours whether herbicide resistant weeds are becoming a problem in your region?

Table 8. (cont'd)

Weed Management Practices Variables
Basic Herbicide Usage
Over the past two years what percentage of your fields on your entire farming operation did you use pre-emergent herbicides?
Over the past two years what percentage of your fields on your entire farming operation did you use post-emergent herbicides?
Integrated Herbicide Usage
Over the past two years what percentage of your fields on your entire farming operation did you use multiple herbicides?
Over the past two years what percentage of your fields on your entire farming operation did you use rotated herbicide modes of action annually?
Over the past two years what percentage of your fields on your entire farming operation did you use herbicide mixes?
Low Integrated Weed Management
Each field that I manage is scouted before making a weed management decision for that field
I use hand weeding in some fields and border areas to control weeds
On a field-by-field basis, I vary weed management practices, including herbicide use
High Integrated Weed Management
Over the past two years what percentage of your fields on your entire farming operation did you use high seeding rates/planting densities?
Over the past two years what percentage of your fields on your entire farming operation did you use cover crops or mulches?
Over the past two years what percentage of your fields on your entire farming operation did you chose your planting date to reduce weed competition?
Over the past two years what percentage of your fields on your entire farming operation did you use narrow rows?
Over the past two years what percentage of your fields on your entire farming operation did you use weed maps?

CHAPTER 3

Mixed Methods Research and the US Farming Population:
A Case Study and Theoretical Foundation in Relational Pragmatism

INTRODUCTION

Researching farmers in the US is of the utmost importance to promote environmental, social, and economic sustainability. Surveys in particular can be extremely useful due to their ease, low cost, potential for large samples and high generalizability. However, such research is increasingly difficult –farmers are becoming over-surveyed and less likely to respond to the multitude of surveys they receive (Pennings, Iwrin and Good 2002; Weber and Clay 2013). For example, Gerling, Tran and Earp (2008) found that when it comes to surveys, US farmers are extraordinarily busy and generally very private – leading to a 33 percent nonresponse rate for the census-like Agricultural Resource Management Survey (ARMS) conducted by the USDA. More generally, Pennings et al. (2002) report the average farmer survey nonresponse rate to be upwards of 80 percent. This trend is true not only of the US farming population – many groups in the US have become 'over-surveyed' with resulting higher nonresponse rates (Groves 2011). Therefore it is clear that in certain research contexts surveys need to be altered or supplemented in order to provide results that minimize potential errors such as nonresponse and measurement errors (Cui 2003; Ouimet, Bunnage, Carini, Kuh and Kennedy 2004). Although tailored design of surveys can address such issues to a degree (Dillman, Smith and Christian 2014), a given study may also significantly benefit from an additional form of data collection. Using multiple methods of data collection for one research project is termed mixed methods, and has become increasingly popular to collect richer data than a single method may be able to provide (Creswell 2014; Creswell and Plano Clark 2011; Johnson and Onwuegbuzie 2004).

At the general level, mixed methods are useful in that quantitative and qualitative approaches can be combined for overlapping strengths and a minimization of their relative weaknesses (Creswell 2014). For example, qualitative methods such as focus groups or interviews can be used to generate theories and hypotheses which are then tested for generalizability through quantitative methods such as surveys. This has a number of advantages, including development of more appropriate quantitative questions and triangulation of data for a holistic picture of the issue at hand (Creswell 2014; Johnson and Onwuegbuzie 2004). Despite these benefits, however, some experts in methodology argue that mixing quantitative and qualitative methods is impractical due to fundamental paradigmatic differences underlying these methods (e.g. Ahram 2011; Giddings 2006).

Starting from a point of pragmatism, I recognize but bypass the argument that there is no theoretical justification for mixing methods. This avoidance of a circular paradigmatic argument is advocated by Kivinen and Piiroinen (2004; 2007) and Zhu (2011). Instead, I focus on the development of a theoretical framework for *using*, as opposed to *justifying the theoretical compatibility of,* mixed methods research. Grounded in pragmatism and a recognition of the researchers' relationships to significant others, I term this framework relational pragmatism. Based on this theoretical grounding and an associated case study of US farmers' perspectives on herbicide resistant weeds, I investigate how mixed methods as conceptualized under relational pragmatism can be used to supplement survey research and produce a more complete understanding of hard-to-study populations.

LITERATURE REVIEW

RESEARCHING FARMERS

In recent decades, surveying has evolved rapidly in conjunction with technological and cultural changes in the US. Cell phones irreversibly altered the telephone survey, while Internet surveys have burgeoned in use while also facing unique design and access problems. It is not unusual for telephone and email surveys to experience response rates in the single digits (Dillman et al. 2014). Survey work on farmers has not been exempt from these trends – although there is limited research on this subject, with an even smaller body of literature aimed at how farmer surveys specifically may be improved. Drawing on these limited resources, I attempt to paint a picture of the struggles faced by researchers studying US farmers in the modern day.

The largest and most comprehensive study of US farmers is the USDA's Agricultural Resource Management Survey (ARMS). This survey covers farms making $1,000 or more in the 48 contiguous states. It is conducted on a longitudinal basis with the aim of providing extremely detailed and generalizable data about the status of US farmers and farming. Still, even this sophisticated survey suffers from some degree of nonresponse. In fact about one third of farmers who receive the ARMS survey fail to respond to it (Gerling et al. 2008). In a follow-up study to determine why these respondents did not complete the ARMS survey, Gerling, Tran, Earp and Crawford (2008) found that the main reasons were 1) being too busy 2) requested information is too personal/none of your business, 3) no reason given, 4) not wanting anything to do with the government, and 5) specifically declining to fill out surveys that request financial information. Of the non-respondents that they were unable to contact for a follow-up interview, Gerling et al. (2008b) found that the most common reason for being unable to contact the respondent was that they were simply an extremely busy person and therefore unavailable.

In their research on how to improve farmer surveys, Pennings et al. (2002) found trends similar to those identified in the ARMS nonresponse study. They conducted an experiment in which they sent a mail survey to 100 farmers in the US asking about market advisory services. This survey had a response rate of only 12%. In order to improve this, Pennings et al. called all non-responders and asked them follow-up questions about why they did not return the mail survey. Through their telephone conversations, Pennings et al. came up with a list of recommendations outlining what farmers had reported would entice them to respond to a survey. These included sending the survey in winter months, making the time to complete the survey less than 13 minutes, including compensation if the survey was from a private company, avoiding questions requiring the consultation of records, and emphasizing that the research was conducted by a university and not the government (if applicable). Using these recommendations, Pennings et al. redid their initial survey and sent it back out to a new sample of farmers. This time, they received a 35% response rate – a statistically significant improvement.

Pennings et al.'s findings line up with the ARMS findings in several ways. Particularly, there is a need to make surveys shorter – many farmers are simply too busy to consider completing them. There was also a general dislike or mistrust of private company and government surveys – farmers did not feel comfortable sharing information, especially financial information, with these entities. Two things are made clear – 1) if the survey is not from a liked or trusted source farmers are much less likely to complete it and 2) farmers are extremely busy and therefore less likely to complete a survey especially if it is long and complicated.

Although Pennings et al.'s study shows that increased research into farmers' survey habits could significantly improve response rates and associated data quality, there are those who advocate moving away from surveys entirely (e.g. Cornwall et al. 1994). Indeed, focus groups represent one of the areas where innovation in researching farmers is expanding, with the integration of, for example, participant photography, visual vignettes, and map drawing (e.g. Fairweather and Hunt 2011; Gotschi, Delve and Freyer 2009; McLees 2013; Naylor, Maye, Ilbery, Enticott and Kirwan 2014). Although this type of innovation is exciting and has potential to improve data on farmers, it is impractical and undesirable to eliminate surveys entirely. I argue that surveys need not be dispensed of as a data collection tool for farming populations – rather their use can be improved through their integration into a mixed methods format. Specifically, I focus on the mixed use of surveys and focus groups for data collection. Not only are these already common research methods for studying farmers, but their integration represents one of the most well-known and easy to apply forms of mixed methods (Morgan 1997), making them an ideal starting point for the application of mixed methods to the US farming population. I begin by reviewing mixed methods generally, followed by the mixed use of focus groups and surveys in particular.

MIXED METHODS

Mixed methods research, of which combining focus groups and surveys is one example, involves the connection of qualitative and quantitative data in response to a research question. It originated in the late 1980's and has been advanced within the disciplines of education, sociology, and health sciences in particular. Prevailing wisdom dictates that mixed methods, much like other methods, should be chosen with care based on the needs of the research problem at hand (Creswell 2014). In particular contexts, mixed methods may be the most appropriate design due to its usefulness for development and complementarity, support of exploratory and explanatory research designs, and the ability to work well within interdisciplinary research.

There are five major purposes for mixing methods as outlined by Johnson and Onwuegbuzie (2004). These are 1) triangulation, which seeks convergence; 2) complementarity, which seeks elaboration or clarification; 3) initiation, which discovers contradictions; 4) development, which uses the findings of one method to inform the other; and 5) expansion, which seeks to expand the range of research. While Johnson and Onwuegbuzie consider these to be distinct rationales, I believe that these purposes can, and often do, overlap and exist in tandem. This list may be better considered as a collection of convenient labels rather than an exhaustive account of distinct purposes. Still it is useful for understanding and standardizing the rationale for choosing a mixed methods design.

Qualitative and quantitative data can be integrated in a specific mixed methods design based on the timing of, and emphasis on, each technique. There are six major designs resulting from this combination – each of which emphasize and are suited to the different purposes listed above. These designs are 1) convergent - different data complement each other on the same topic; 2) explanatory sequential - qualitative methods are used to explain initial quantitative results; 3) exploratory sequential - qualitative findings are generalized to a larger quantitative sample, 4) embedded - different types of data are used for different questions, 5) transformative - focused on advancing social justice, and 6) multiphase – using different methods in multiple phases to advance one objective (Creswell and Plano Clark 2011). These methods can be chosen based on the structure of the research question, the makeup of the research team, and the purpose/desired product of the research.

Along with the opportunities of mixed methods research come some challenges. Mixing several different methods can be difficult, and the researcher must have a solid understanding of all the methods in use (Giddings 2006). Concomitant with this is the danger that one preferred method will dominate, leaving the other in a weak supporting role (Mason 2006). This points out a case in which mixed methods should not be used – if the researcher is completely unfamiliar with either qualitative or quantitative research, attempting to use both is unlikely to result in valid and meaningful results. Additionally, certain research questions are best answered with one method – attempting to shoehorn in another for the sake of appearing complex may lead to confusing, misleading, expensive, and inaccurate data. For instance, a researcher may be interested in collecting narratives from sexual assault survivors in a university town in order to explore how the university can better support this group of people. Attempting a mixed methods design in this situation would be unnecessary, as qualitative methods will be sufficient, and generalizability of findings is not a key goal. Additionally, a quantitative portion would take time and resources away from the more appropriate deep narrative focus of the qualitative portion of the study.

Using mixed methods should not be undertaken lightly, as it is complex and not appropriate for every research problem. It requires a clear understanding of quantitative and qualitative techniques, as well as their philosophical foundations. Some scholars also argue that quantitative and qualitative paradigms cannot be mixed (e.g. Giddings 2006) – therefore a clear rationale for why this mixing is appropriate for your research problem is fundamental. The goals of the study, as well as available human and non-human resources, should determine the choice of mixed methods.

MIXING FOCUS GROUPS AND SURVEYS

Although the body of literature on combining focus groups and surveys is small, it is still one of the most thoroughly studied forms of mixed methods (Morgan 1997). This is in part because the advantages and disadvantages of focus groups and surveys are reasonably compatible. Focus groups have the advantage of directly observing interactions, similarities, and differences; while surveys provide data on a wide range of people, enable theory testing, and have an expansive and detailed guiding literature (Bryman 2001; Dillman et al. 2014; Groves et al. 2013). Where focus groups are concentrated on developing theories and hypotheses, allowing for comparisons, exploring experiences and perspectives, and detailing complex behavior; surveys are useful for *testing* such theories, as well as more general questions about self-reported beliefs and behaviors, attitudes and opinions, characteristics, expectations, self-classification, and knowledge (Neuman 2003; Stewart and Shamdasani 2014).

In contrast to these advantages, limitations to focus groups include low generalizability; the potential for dominant participants to take over; difficulty analyzing, summarizing, and interpreting data; and the potential for moderator bias (Bryman 2001; Stewart and Shamdasani 2014). Surveys in turn face access impediments, cost inflation, low response rates, incomplete address lists, and a population that is simply tired of answering surveys (Dillman et al. 2014; Groves 2011; Pennings et al. 2002). They also lack flexibility and are poorly suited to ‘why’ questions, hypothesis and theory generation, deep understandings, and context driven studies (Neuman 2003; Wolff Knodel and Sittitrai 1993). While these limitations are not insurmountable, it is also clear that focus groups and surveys could benefit from each other. Well-designed focus groups can help address surveys’ inability to form theories and lack of detailed information while appropriate surveys can supply generalizability and hypothesis testing to focus group findings.

At the conceptual level, Groves et al. (2013) advocate for using focus groups in advance of surveys, i.e. in an exploratory mixed methods design, in order to determine how respondents structure knowledge about a question and identify common terms they use. This enables researchers to write appropriate survey questions and adds depth to the quantitative phase. DeVellis (2011) similarly mentions focus groups as a tool for identifying terms, ideas, and vocabulary that are easily understood by your group of interest and can be incorporated into your survey. Morgan (1997) specifies this process, stating that focus groups contribute to surveys by capturing all domains to be measured, determining what dimensions make up these domains, providing item wording, and generating hypotheses.

In addition to these conceptual reasons for mixing focus groups and surveys, several empirical studies argue for their utility as well. In their research on hazardous waste risks, Desvouges and Frey (1989) found that focus groups helped to identify possible contaminating opinions and lines of reasoning, inform and educate the researcher, construct appropriate measurement scales, classify levels of knowledge, and identify troublesome language or terms to be avoided in the survey. Fuller, Edwards, Vorakitphokatorn, and Sermsri (1993) obtained similar advantages by using focus groups to adapt a pre-existing survey instrument from a U.S. population to one in Thailand. They found that focus groups provided proof of their theoretical concept, introduced new questions, bridged the language gap, got researchers closer to the data, and improved the phrasing of survey questions. Wolff, Knodel, and Sittitirai (1993) also used focus groups to improve a survey in Thailand. They summarize that "From a broad social science perspective, the justification for integrating survey and focus group methods might best be summarized as the potential gains to the validity of conclusions from any one study and to the generation of new hypotheses that advance research agendas" (Wolff et al. 1993, p. 134).

Although the majority of literature on combining these methods focuses on how focus groups benefit surveys, the opposite can also be true. Surveys are capable of testing and generalizing focus group findings, enabling complex statistical analysis, summarizing trends, and enhancing the clarity of data interpretation (Creswell 2014; Creswell and Plano Clark 2011; Dillman et al. 2009). For these and other benefits to be successful, however, one must pay careful attention to the process of combining focus groups and surveys in a methodological design.

The first step in mixing focus groups and surveys in an exploratory design is the analysis of focus group data to create the survey instrument. This involves coding, choosing quotes, and identifying themes. These can then be used to design items, variables, and scales for the survey instrument (Creswell and Plano Clark 2011). It is also useful to look for natural response categories and pay attention to participants' language use in order to develop appropriate terms for question items (Creswell and Plano Clark 2011).

As Creswell (2014) points out, it is difficult to develop survey items from focus group analysis. It is time consuming and requires a researcher with experience in both qualitative analysis and survey creation. There is always the possibility of misinterpreting the focus group data, or transforming it ineffectively into a question set. The reliability and validity of the survey would then be compromised – pointing out the importance of very careful analysis and transformation of the focus group data. For this reason, conducting cognitive interviews of the survey, ideally with participants from the focus groups, is useful for clarifying that the questioning route is clear and true to the focus group themes. Still, focus groups may not be representative of the survey population and can be unreliable (Groves et al. 2013). If the focus groups are done poorly, or with an inappropriate sample, the resulting survey will have little validity and be useless for generalizability. Therefore any combination of these techniques must be undertaken with great care for the quality of each method and their relationship to the other. However carefully this is done, there are still those who would argue that focus groups and surveys have such fundamental paradigmatic differences that they should not be combined at all – a view that is challenged in mixed methods literature by those with a pragmatic orientation (e.g. Creswell 2014; Zhu 2011).

THEORETICAL FOUNDATION

There has been some debate over whether quantitative and qualitative methods can really be mixed, given that they follow different methodological orientations. Quantitative methods are commonly positivistic, focusing on experimental designs, comparative cases, detachment of the researcher, and established procedures. Qualitative methods are linked with phenomenology and post-positivism, focusing on an immersed researcher, description, detail, and complex definitions of constructs (Ahram 2011; Firestone 1987; Giddings 2006). Therefore some posit that these methods are too fundamentally different to be mixed effectively. For instance, Ahram (2011) argues that mechanism muddling, conceptual slippage, and remedies for these issues force mixed methods researchers to choose between favoring qualitative or quantitative interpretations – and therefore between depth or breadth of findings. Similarly, Giddings (2006) argues that within mixed methods studies positivism will always dominate while qualitative methods are confined to a ‘supporting’ role (i.e. Marsland, Wilson, Abeyasekera and Kleih 2000). Although mixed methods may favor one or the other, it is my view that quantitative and qualitative methods are less fundamentally different than is sometimes assumed – both contain varying degrees of subjectivity, objectivity, and neutrality, with the fundamental purpose of each focused on creating a narrative to elucidate the research problem. Therefore, with careful attention to detail and a commitment to balancing qualitative and quantitative interpretations, I believe mixed methods to be a legitimate methodological enterprise.

Other researchers who argue for the utility of mixed methods. Greene (2008) for instance believes that mixed methods have the potential to be a distinct methodology that legitimates multiple truths, while Bryman (2001) points out that quantitative methods already employ some qualitative principles and techniques, as well as the reverse. Bryman also argues for the technical viewpoint – that connections between methods and paradigms are not fixed. This is similar to the pragmatist worldview that many scholars advocate for as a paradigmatic underpinning for mixed methods research (e.g. Creswell 2014); a worldview which I adopt in this chapter.

Pragmatism as an ontological commitment argues that philosophical topics should be viewed in terms of practical uses, and that thought is a tool for prediction, problem solving, and action. It focuses on day-to-day social life, social practices, and people's intertwined activities instead of larger meta-theoretical questions about the structure of reality (Kivinen and Piiroinen 2004). In this sense, explanation and prediction are prioritized over description, and pluralist interpretations are accepted. As a model of action, pragmatism sees ends, or actions, as the result of a dominant motive (Joas 1993).

In application to mixed methods, pragmatism can be used as a philosophical foundation to argue that the ends, in this case the choice of methods, are the result of the researchers' dominant motivation. It allows researchers to bypass paradigmatic struggles about what should work in theory and focused instead on which method, or combination of methods, work in reality (Zhu 2011). In the pragmatic view, methods are chosen based on what is the most effective way to answer a research question, with the possibility of adjusting methods mid-research to suit changing goals and purposes (Johnson and Onwuegbuzie 2004; Mutch, Delbridge and Ventresca 2006).This makes mixed methods practical "…in the sense that the researcher is free to use all methods possible to address a research problem" (Creswell and Plano Clark 2011, p. 13). Thus the pragmatic rule is that a researcher should combine methods in a way that best fits their research question given the empirical and practical consequences (Johnson and Onwuegbuzie 2004

Although pragmatism has been used to justify mixed methods as essentially 'do-able' (Creswell and Plano Clark 2011; Johnson and Onwuegbuzie 2004), it fails to provide guiding principles about *how* exactly to develop and implement a mixed methods study. Therefore mixed methods lacks anything similar to survey research's guiding theory, social exchange theory, as applied by Don Dillman. Social exchange theory was developed to be a general model of behavior and interaction, positing that social norms are developed to guide interaction. These norms include reciprocity, trust, and altruism (Dillman et al. 2014). Using this theory as a guide, Don Dillman, suggests an application to survey research in which surveys can be improved by considering the benefits and costs of the survey to potential respondents. Social exchange theory thus dictates the guiding principles underlying effective survey research – 1) increase the benefits to participants, 2) decrease the costs to participants and 3) build participants' trust (Dillman et al. 2014). These principles then translate into actual practices of survey development and implementation – such as limiting the length of the survey (decreasing the 'cost' to participate), using university branded envelopes (increasing participants' trust), and making the survey fun and interesting (increasing benefits) (Cui 2003; Dillman et al. 2014). Here I will attempt to develop a similarly foundational guiding theory for mixed methods – one based on relational pragmatism.

While pragmatism has applicability to the development and implementation of mixed methods research, its focus is on the researchers' choice of effective methods. It thus effectively ignores the important role of social interaction between participants, researchers, and other significant actors. In order to remedy this, I introduce the concept of relationalism to supplement a pragmatic choice of mixed methods – introducing a guiding theory termed relational pragmatism. This helps address Zhu's assertion that "no methodology by itself delivers efficiency, purpose, creativity, or fairness. What matters is its *continuing associations with other actors* which are always multiple, specific and changing" (2011, p. 792, emphasis added).

Relationalism as a theory prioritizes the *relations* between actors (both human and non-human) as the essential dynamic that creates society and determines all that lies within perceivable bounds (Archer 2010; Depelteau 2015; Emirbayer 1997). It moves beyond absolute truths, and beyond the structure/agency divide, to focus on fields of transaction. Transactions in relationalism should not be conceived of as mere interactions, but rather as subjects acting because of themselves *and* others *within* a specific context (Depelteau 2015; Emirbayer 1997). Therefore every act of knowing is essentially relational (Bouwen 2001). Relationalism in a methods sense has a variety of forms, from concentrating on the dialogical exchanges between participants to advocating for a deeper understanding of an ethnographer's emotions as produced by relations with the subjects (e.g. Bouwen 2001; Stodulka 2015). For my own use, I define a relational methodology as prioritizing and utilizing the relationships, both pre-existing and future, of the researcher, the respondents/participants, and others whose expertise may be of use.

Combining the perspectives of pragmatism and relationalism, I advocate for a relational pragmatic approach to conducting mixed methods research. This approach is founded on building new relationships and drawing on existing relationships with local charismatic, important, and expert persons – as well as building mutually beneficial relationships with the individuals that are being studied. These relationships help define the realistic, that is pragmatic, ways in which to choose and implement a mixed methods study. Mixed methods is already suggested as being best conducted by an interdisciplinary research team whose variety of expertise enables the effective use of a combination of qualitative and quantitative methods. In relational pragmatic terms, an interdisciplinary team is also useful in that the team members' existing relationships with experts and significant others in their fields can be drawn upon to, for example, recruit focus group participants or better field-test and advertise a survey. Additionally, relational pragmatism takes into account the *respondents'* relations – for instance their trust or distrust in certain groups and institutions, their relationship to place (both in a community and nature sense) and their transactions with peers.

This pragmatic focus on relationships to guide the choice and implementation of mixed methods should not be taken as a replacement for more method-specific theoretical foundations, such as the aforementioned social exchange theory. Indeed, I advocate the continued use of such principles and theories within the appropriate portions of the mixed methods study (i.e. using social exchange theory for a survey portion). However relational pragmatism goes beyond a single method theory and advocates the recognition and development of relations in order to choose an appropriate combination of methods that best suits the research question, the capabilities of the research team, and the characteristics of the population of interest. As an actionable process, relational pragmatism in the application of mixed methods can be broken down into the following set of guiding principles:

1) Identify team members' pre-existing relationships with significant actors in the area of study
2) Identify how the population of interest relates to the position of team members and other significant actors (both human and non-human)
3) Choose your methods based on the research goals and pragmatic relationships of the researchers and participants.
4) Draw upon pre-existing relationships to facilitate the development and conduct of different methods portions

5) Develop mutually beneficial relationships with participants and other significant actors throughout the process in order to best facilitate a) participant engagement and actionable outcomes and b) effective data collection.

These principles should not be considered a step-by-step list so much as an iterative process of research in which relations are constantly in flux and affect the next step of research development and data collection in a non-linear way. In order to further explicate this process and the utility of a relational pragmatic approach to conducting mixed methods, I will present a case study to ground and explore the process. This case study involves an interdisciplinary research team of which I was a part. We used exploratory mixed methods to study farmers' herbicide resistant weed control, and drew specifically on relations to accomplish our research goals. By following our research process, and briefly analyzing how it impacted the quality of our results, I hope to shed light on the usefulness and applicability of a relational pragmatic approach to mixed methods research.

CASE STUDY

OVERVIEW

The case study I will be exploring took place from early 2015 to early 2016 as part of an interdisciplinary project funded by the USDA's Agriculture and Food Research Initiative. Team members were from across the US and had specializations in sociology, weed science, and agricultural economics. The goal of the project was to identify social dimensions related to US farmers' herbicide resistant (HR) weed control – i.e. why they make the weed management decisions they do, how they perceive the issue of herbicide resistance, what barriers they believe prevent them from managing HR weeds, and what their hopes are for the future of weed control. This study had the particular problem/blessing of being one of the first to ask these questions.

Very little is known about how farmers think about HR weeds – although there have been plenty of studies related to the environmental, agricultural, and economic impacts of these weeds (e.g. Culpepper, Owen, Price and Wilson 2012; Egan 2014; Gould 1995; Griffin 2015; Inman et al. 2016). These are well-researched areas because HR weeds present a significant hazard to modern conventional agricultural practices – they threaten the use of widespread mono-cropping as well as weed management plans based on herbicide application alone. However, sociologically, herbicide resistance is fundamentally a common pool resource problem and has been understudied in this sense. The common pool resource in this case is weed species that are susceptible to commonly used herbicides (Ervin and Jussaume 2014). There are plenty of 'free-riders' in this system who mess things up for everyone else – for instance even if a farmer does everything possible to prevent herbicide resistance on their own fields, they can very easily get HR weeds from less conscientious neighboring farmers (Gould 1995; Webster and Sosnoskie 2010). Therefore it is fundamental to understand how farmers think about herbicide resistant weeds and interact with their neighbors and their community, if at all, to aid in the control of these weeds.

All this leads to a complicated topic for research. Since little is known about farmers' relation to and perspectives on HR weeds, it would be impractical to develop a survey right off the bat – we had no specific hypotheses to test and did not yet know what kinds of questions to ask. Similarly, although a qualitative methodology could identify the HR weed themes and help us develop hypotheses, the nature of this study required the ability to generalize across populations and understand HR weed management culture across the US. For these reasons, the research team decided to conduct a mixed methods study in which focus groups were followed by a larger survey intended to generalize the themes identified in the focus groups. This type of mixed methods study is termed exploratory, and allows for the quantitative testing of themes identified in a qualitative study (Creswell 2014). For our research on the understudied social dimensions of farmers' HR weed management, this approach is particularly appropriate as it allows the identification of themes and language from the focus group which can then be expanded upon to inform a more generalizable survey. This aligns with the goals of development and complementarity (Johnson and Onwuegbuzie 2004) – we seek to use the findings of one method to a) inform and b) clarify the other.

Aside from choosing an exploratory mixed methods design for its utility in addressing our research goals, it was also practicable from a standpoint of relational pragmatism. I will begin by explaining how relational pragmatism informed the focus groups, followed by the framework's application to the development of the survey and the survey implementation. All of these research steps would have been impracticable were it not for the utilization of relationships between team members, significant actors, and participants.

FOCUS GROUP DEVELOPMENT AND IMPLEMENTATION

For the focus group portion of the study, we followed the 5 guiding principles of a relational pragmatic framework outlined in the theoretical section of this chapter. We began by identifying team members' pre-existing relationships with significant actors in the area of study (principle 1). This was done in tandem with principle 2 – identifying how the population of interest relates to the position of the team members and other significant actors. Several of our team members had pre-existing relationships with local extension educators in Iowa, Minnesota, North Carolina, and Arkansas. These extension educators, in turn, were trusted advisors who frequently interacted with farmers in their area of the state.

Therefore we knew that the population of interest – corn and soybean farmers – had pre-existing, positive and trusting relationships with the extension educators known to members of our research team. Combined with our research goals of identifying poorly understood HR weed management attitudes, actions, etc., this made focus groups an obvious choice of research method (principle 3). Our research team had a pre-existing chain of relationships that drove the pragmatic decision to recruit focus group participants through extension educators in Iowa, Minnesota, North Carolina, and Arkansas (principle 4). Without these relationships, the focus groups would have been extremely difficult to organize and it is likely that we would have had far fewer participants. One instance in which pre-existing relationships facilitated the practicability of conducting focus groups stands out in particular. In North Carolina, we had the misfortune of timing the focus groups directly after the first big rain of the spring. This meant that farmers who had previously agreed to participate in a focus group dropped out due to the need to be out in their fields. This could have limited the intended 4 focus groups in North Carolina to only 1; however the team member in charge of contacting extension educators made several calls and was able to arrange an impromptu focus group of mostly retired older farmers. This turned out to be an extremely interesting group with some unique perspectives that we would not have otherwise obtained. The relationship of the team member with local farmers, extension educators, and other agricultural actors was necessary to facilitate this outcome.

Although this method of focus group participant recruitment was extremely effective, it had its inherent biases as well. Specifically, the extension educators who assisted in the recruiting of the focus group participants expressed that they had recruited growers whom they considered to be their ‘best’ in terms of management practices, yield, and/or communication with extension. Our participants often reflected this through statements that they were attending the focus group because they had a good relationship with the extension educator. Therefore our participants were more likely to be farm managers who, in the view of extension educators, are at the forefront of HR weed knowledge and management. These participants may be more innovative than typical growers in these states, as well as more involved in extension activities.

As an result of pragmatically employing the teams’ relationships with extension educators, we conducted a total of ten focus groups, with four in Iowa, two in Minnesota, two in North Carolina, and two in Arkansas. Although not representative of all agricultural producers in those four states, these focus groups provide a cross section of producers from agricultural areas where weed resistance is becoming an important agricultural production issue. For a summary of focus group demographics, refer to Table 9.

The focus groups were most often conducted at a university extension building, although several took place at community centers or restaurants. This reflected team members’ and extension educators’ understanding of participants’ relations with human and non-human actors (principle 2) – these were locations that participants commonly visited for either social, professional, or personal gratification. They were familiar and comfortable with these places based on previous relations with them – therefore they were chosen as particularly good focus group locations since they would put participants at ease and facilitate easy discussion.

Focus groups lasted approximately one and a half hours each, and were audio recorded. A secondary researcher took notes on general themes while the primary researcher facilitated the discussion. Before beginning, participants were briefed on the purpose of the focus groups and encouraged to state any differing opinions during the discussion. They then filled out a consent form and a short demographic questionnaire. Following an 'ice-breaker' question, there were three main lines of questioning; 1) how a farmer *should ideally* react to herbicide resistant weeds on their own farm versus how they *would actually* react, 2) how a farmer *should ideally* react to herbicide resistant weeds on their neighbor's farm versus how they *would actually* react, and 3) whether farmers view herbicide resistance as a short- or long-term problem.

In addition to drawing on relationships with extension educators to facilitate recruitment of focus group participants, extension educators also played a role in conducting the focus group interviews. This helped to allay one of the concerns of the research team – that the sociologists conducting the focus groups were unlikely to be particularly trusted or liked by rural, and often conservative, farming populations (principle 2). For this reason, the extension educators who recruited the focus group participants were invited to sit in on the focus groups. This had the dual purpose of putting the focus group participants at ease via the presence of a trusted and well-known expert, as well as compensating the extension educators for the role they played in recruitment (principle 5).

All of the extension educators expressed an interest in attending the focus groups, as they themselves were often curious or stymied by farmers' attitudes and management practices related to herbicide resistant weeds. It is extremely important that the relationships drawn upon to facilitate data collection not be abused – that there is a reciprocity in order to avoid exploitation. The ability of extension educators to sit in on the focus groups, as well as later dissemination of the results to participating extension educators and farmers, fulfilled this role. Therefore it was considered wise to include them in spite of Morgan's (1997) recommendation against non-participants sitting in on focus groups. Although their presence may have influenced farmers' responses to a degree, the participants were clearly already very trusting of their extension educator. We also instructed extension educators to remain silent observers and not contribute to the discussion. Therefore we believe the bias to have been minimized.

Importantly, after coding and identification of themes, we created a report to send back to focus group participants and the associated extension educators. Our goal was not to exploit these relationships, but rather expand upon and maintain them, ensuring that participants were benefitting as much as we were. At the conclusion of the focus groups, a majority of focus group participants expressed a desire to obtain the results – therefore we honored this request to the best of our ability. We additionally plan to go back to several of these communities to present the survey results and associated recommendations about HR weed control.

SURVEY DEVELOPMENT AND IMPLEMENTATION

Following the focus group coding and analysis, a survey was developed based on the themes, ideas, hypotheses, and language discovered in the focus groups. This enabled the research team to use the language and concerns of the farmers within the survey itself, eliminating confusing wording that might be interpreted incorrectly. Part of this process involved cognitive interviews with farmers – another role in which relational pragmatism played a large part. Farmers who were willing to take the survey in front of a team member and give their feedback were recruited either directly by a research team member or by extension educators the team was familiar with (principle 1). This made cognitive interviews a pragmatic choice as they were easy to recruit for and facilitate (principles 3 and 5). The feedback given by these individuals was invaluable in refining the survey themes and wording to make sure the questions were measuring the intended constructs.

Additionally, the relationships identified *during* the focus groups were used in the development of the survey research portion (principle 5). For instance, we noted in the focus groups that farmers tended to distrust government officials. Therefore when creating the survey we made certain to emphasize that the survey was coming from research associated with various universities. We also employed existing relationships with extension educators and local agricultural new sources to advertise the survey to potential respondents, building on these relationships of trust to encourage potential respondents to take our survey seriously (principles 1, 2 and 4). Therefore the survey itself was the product of a large web of relationships – both those that existed before the start of the research (i.e. between team members and extension educators) and those that developed during the project (i.e. between the focus group facilitator and the participants). It therefore had the benefit of being backed by liked and trusted sources, a fundamental element of successful farmer surveys as identified by Gerling et al. (2008) and Pennings et al. (2002).

The survey developed based on the focus group results was sent to 9,000 corn and soybean farmers across the US in winter of 2015 and spring of 2016 – with 839 returning usable. This gives us a response rate of 9.3 percent – just below the national average farmer response rate of about 10-20 percent (Pennings et al. 2002). This was, largely, a result of our chosen sampling frame. We used a marketing company that maintains a list of farmer mailing and email addresses – specifically those farmers who subscribe to certain agricultural mailing lists. Unfortunately, it appears that this list was not maintained to remove individuals who were no longer farming. Evidence of this comes from the numerous calls we received stating that the intended survey recipient had died, retired, moved on from farming, etc.

However, the survey instrument did prove to be very effective for the surveys that were returned. There was very little missing data, indicating low measurement error and a high completion rate once participants had started the survey. Additionally, the survey proved to be reliable when similarly worded questions were compared to those from the 2012 Iowa Farm and Rural Life Poll (see Tables 10 and 11). This shows that the relational pragmatic approach used in our focus groups, survey development, and survey implementation appropriately complemented the social exchange theory of survey research. Our team's pre-existing relationships with extension educators allowed for the conduct of very successful focus groups – allowing us to investigate participant relationships and establish relationships of our own with our population of interest. This was then useful in the development of a survey that adheres to the principles of social exchange theory.

In line with social exchange theory, we were able to draw on our knowledge from the focus groups to conclude what kinds of language, formatting, etc. would be seen as highly beneficial to our sample, as well as what some of the costs might be (for instance that participants were unlikely to trust a survey from the government). This was supplemented by drawing on relationships with farmers to do cognitive interviews of the survey, further identifying costs and benefits and allowing us to better tailor the survey to a farming population. Finally, relationships with extension and various agricultural newsletters allowed us to build on the social exchange principle of increased trust – external experts whom farmers already had trusting relationships were entailed in notifying them of the coming survey and encouraging them to complete it.

OUTCOMES

Overall, relational pragmatism worked very well as a theoretical framework for the development and implementation of an exploratory mixed methods study. Not only did it facilitate the choice and conduct of the focus groups, but aided in the transformation of the focus groups to an internally valid survey instrument. Our team drew on existing relationships in a way that emphasized a pragmatic approach – answering our research question to the best of our ability with the resources at hand. Particularly for an interdisciplinary team of researchers, this theoretical framework proved very successful – we would have been able to conclude much less from each method alone.

If the focus groups had been used alone, that is, not in conjunction with a survey, we would have still learned a great deal about how a certain subset of farmers think about and manage herbicide resistant weeds. Given that this subject is severely understudied, a qualitative methodology was fundamental to the development of theories and hypotheses. The focus groups provided these necessary materials of research, particularly guiding us to develop hypotheses about how farmers' techno-optimism and individualism impacted their perspectives on herbicide resistant weed management.

However, while focus groups are useful for *generating* theories and hypotheses, as well as hinting at relevant trends, they cannot *test* these theories/hypotheses/trends. Nor can they breakdown larger trends into smaller factors and predict how these factors influence one another and are related statistically. Therefore without the focus groups, our research would have ended with the generation of theory, hypotheses, and themes. Obviously this is still extremely valuable

– however the *goal* of our research was not only to identify these elements, but also to test their viability and impact on farmers' actual weed management practices. In this sense, the survey supplemented the focus groups with the testing of theories and hypotheses, as well as the refinement of themes into multiple factors.

For example, we were able to conduct an exploratory factor analysis of techno-optimism and individualism variables inspired by the focus group findings. We discovered that within the survey data these themes broke down into smaller constituents – techno-optimism was made up of 1) faith in external experts and 2) faith in herbicides while individualism was made up of 1) belief in the autonomy of every farmer and 2) dislike of any form of outside regulation. We were also able to test how these different elements impact actual weed management practices such as rotating herbicide modes of action and tillage. This gives us a clearer picture of how a diverse population of farmers think and act regarding herbicide resistant weeds, enabling a larger degree of generalization and a stronger theoretical foundation.

Similarly, the survey would still have been useful without the antecedent focus groups. Based on our team members' diverse expertise, we could have come up with relevant and meaningful survey questions related to farmers' management of herbicide resistant weeds. However, having the focus groups take place ahead of the survey helped to *verify* the utility of questions and theories the research team already held, as well as *identifying* themes and *generating* theories that had not previously been considered. For instance, we had not expected individualism to be so pronounced or have as strong an impact on farmer collaboration as the focus groups suggested. This led us to incorporate more questions on individualism and working with one's neighbor in the survey. Additionally, the focus groups provided information on how best to phrase certain questions and how to present the survey to farmers to elicit the best response. Thus the focus group data helped inform the survey so that we were able to ask questions that pertained to farmers' real-world experiences and concerns that we would not have otherwise been able to access.

DISCUSSION

Mixing methods was a pragmatic choice for our case study due to the exploratory nature of our research on farmers' herbicide resistance perspectives, neatly aligning with a methodology based on focus groups and a survey. The focus groups enabled generation of theories and hypotheses, such as those related to farmers' techno-optimism and individualism, while the survey allowed us to test these findings. Although each method was useful on its own, for our specific research questions they were more effective in tandem.

In addition to the pragmatic utility aimed at best accomplishing our research goals, using focus groups and surveys in an exploratory methodology were pragmatic in the sense that our team's existing relationships with significant actors encouraged and facilitated their use. Our case study thus used the guiding principles of relational pragmatism to enhance the viability of an exploratory mixed methods research approach – enabling the best methods combination for addressing our research goals. Below, I outline how we used each principle of a relational pragmatic approach to conduct our exploratory mixed methods study.

The first principle of relational pragmatism is to 'Identify team members' pre-existing relationships with significant actors in the area of study'. In the case of our research team, the weed scientists had close relationships with extension educators in Iowa, North Carolina, Minnesota and Arkansas. This influenced our perception that focus groups with farmers would be possible, and that they should be conducted in these particular states. Additionally, relationships with farmers and individuals associated with agricultural news outlets provided an avenue to test and advertise a survey.

The decision to use these data collection tools was correlated with principle two, "Identify how the population of interest relates to the position of team members and other significant actors (both human and non-human)". We knew our population of interest – corn and soybean farmers – would have pre-existing relationships with extension educators that would aid in the extension educators' recruitment of focus group participants. These relationships were seen as trust-building for both the focus groups and future survey. We also recognized that farmers may not have a positive relationship with sociologists, and therefore decided to have a weed scientist or ag economist from the research team present at each focus group to smooth the dynamic. In terms of participants' relationships with non-human actors, we took care to conduct the focus groups in locations that facilitated farmers' trust – such as familiar restaurants or outreach centers.

The extension educators, who were invited to the focus groups as a reciprocal gesture of goodwill (principle 5), proved expedient in this role of putting focus group participants at ease. It should be noted, however, that farmers who have good pre-existing relationships with their extension educators were likely substantively different from farmers who have poor or non-existing relationships with their extension educators. This may have biased the sample – although the intention of focus groups is not to be representative, we may have missed some themes or hypotheses that could only be represented by farmers who are not in a good relationship with their extension educator. Additionally, the presence of the extension educator at the focus groups is likely to have biased responses to some questions. For instance, our focus group respondents often stated that they would ask their extension educator to mediate any problems between them and neighboring farmers. However this response was less well-represented on the larger survey – more farmers said they would broach the subject directly with their neighbor or not say anything at all. Therefore this admission in the focus groups may have been enhanced due to the presence of the relevant extension educator. Still, we view these as necessary concessions that are forgivable in light of the high rate of focus group attendance and participation elicited via extension educator recruitment and presence in the focus groups.

Given these pre-existing relationships of our team and the exploratory nature of our research, we chose to conduct focus groups and surveys in concordance with principle 3 "Choose your methods based on the research goals and pragmatic relationships of the researchers and participants". As outlined above, this methodology addressed the goals of our research while also being practical from a relational standpoint. These relationships then enable the completion of principle 4 "Draw upon pre-existing relationships to facilitate the conduct of different methods portions". This is clearly outlined in the preceding section.

We were also careful to dedicate ourselves to principle 5 "Develop relationships with participants and other significant actors throughout the process in order to best facilitate a) participant engagement and actionable outcomes and b) effective data collection". Throughout the study, we looked for opportunities to give back to those whose relationships we were drawing on for our data collection. Between including extension educators in the focus groups, disseminating focus group findings back to the participants and extension educators, making the survey as beneficial as possible to respondents, and (in the future) presenting the survey findings to farmers, extension educators, and academic professionals, we believe that we have accomplished this goal.

Additionally, our relationships, both pre-existing and developed, clearly facilitated a more effective data collection procedure. It is unlikely that we would have been able to have the number and quality of focus groups without our team's relationship with extension educators – in addition, the relations we observed and built while in the focus groups were invaluable in constructing and implementing the survey. These results help build the case for a relational pragmatic framework for mixed methods – however it needs further testing, particularly within different disciplines and different mixed methods types. For example, how might a relational pragmatic approach work with a convergent or embedded mixed methods approach? Still, there is both theoretical and empirical evidence that a theoretical framework based in relational pragmatism is an effective grounding for the development and implementation of a mixed methods study – going beyond theoretical justification for mixed methods and proposing a theoretical framework for *doing* mixed methods.

CONCLUSIONS

It has been shown that mixed methods approaches work in practice, even if not always in theory (Firestone 1987; Fuller et al. 1993; Greene 2008; Wolff et al. 1993). Therefore it may be time to set aside theoretical debates about whether mixed methods are paradigmatically compatible and move towards defining theoretical frameworks for actually *doing* mixed methods. In an attempt to start this movement, I have developed a theoretical framework, relational pragmatism, intended to guide the development and implementation of mixed methods research.

Working from a standpoint of relationalism, it is the *relationships* between actors that constitute knowledge, reality, and society. Building on this, I view the use of relationships to facilitate mixed methods research as a logical and pragmatic approach. By determining what relationships exist, as well as forming lasting relationships throughout the research project, the researcher(s) can tailor their approach to obtain the best available data on their population of interest. This may involve drawing on relationships of team members with significant actors in the field of interest (ex. extension educators), various relationships with and between participants, and relationships between different human and non-human actors. These relationships should always be reciprocal in nature, with the researcher ensuring that participants are not being exploited and are instead receiving their fair share of benefits from the relationship with researchers.

This chapter constitutes an early attempt at creating a theoretical framework applied to mixed methods. The case study presented in this chapters employs a relational pragmatism underpinning for an exploratory sequential mixed methods design investigating farmers' perspectives on herbicide resistant weeds. This design was found to provide more complete, detailed, and clarified data than either focus groups or surveys would have alone, providing evidence for the utility of both mixed methods and a relational pragmatism framework for researching US farmers.

Although relational pragmatism proved useful in this case, it should be tested further within this design as well as other mixed methods formats. An additional advantage of this case study was that we had a diverse interdisciplinary research team with particularly high social capital – especially with significant actors whose expertise was relevant to our research goals. When these individuals/relationships do not exist on a research team, there may need to be a more thoughtful and intentional building of relationships or drawing on longer chains of relations. More case studies are necessary to investigate all the potential combinations of methods and research teams to determine their usefulness under a relational pragmatic framework.

It is my belief and experience that a relational pragmatism framework for conducting mixed methods research enhances the viability and quality of the data collected. I hope that others may find this approach useful and test it within their own mixed methods studies. I also encourage researchers to develop and test their own theoretical frameworks for conducting mixed methods – this is the beginning of a larger theoretical debate about how mixed methods *should be done* rather than their inherent compatibility. By comparing and contrasting different theoretical approaches, we can engender a lively and fruitful discussion that will ideally result in the proliferation or consolidation of justifiable ways in which to theoretically ground the practice of mixed methods research.

APPENDIX

Table 9. Demographics of Focus Group Participants by State

	Minnesota	Iowa	North Carolina	Arkansas
Number of Focus Groups	2	4	2	2
Total Participants	16	25	11	12
Males	16	23	11	12
Age	32 - 68	33 - 77	44 - 79	24 - 73
White	16	25	8	11
Acres Managed	200 - 6,200	110 - 6,000	0 - 1,600	2,200 - 9,200
Acres Owned	0 - 2,600	0 - 1,500	0 - 900	40 - 2,200
Farms with Partner	12	18	5	10
Grows Corn	16	25	8	9
Grows Soybeans	16	25	10	12
Grows Cotton	0	0	0	8

Table 10. 2016 AFRI Herbicide Resistance Survey

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
When new weed management technologies are introduced, it is only a matter of time before pests evolve resistance	0.7%	4.2%	13.2%	55.5%	26.5%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Seed and chemical companies need to do a better job of keeping up with the evolution of resistance in weeds	3.1%	7.3%	30.7%	41.8%	17.1%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
By the time a weed develops resistance to an herbicide, at least one new herbicide will have been found to replace it	20.9%	37.7%	25.0%	13.8%	2.6%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Modern agricultural practices contribute to the conditions that spur evolution of herbicide resistant weeds	4.6%	7.2%	19.6%	46.5%	22.1%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Any new chemical mode of action that is developed to control weeds will be overused	3.9%	9.5%	25.5%	45.9%	15.1%

Table 11. 2014 Iowa Farm and Rural Life Poll

	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
When new pest management technologies are introduced, it is only a matter of time before pests evolve resistance	0.8%	2.2%	15.0%	58.8%	23.2%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Seed and chemical companies need to do a better job of keeping up with the evolution of resistance in weeds	1.6%	5.7%	26.9%	49.2%	16.6%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Herbicide-resistant weeds are not a major concern because new technologies will be developed to manage them	20.3%	43.6%	22.1%	12.9%	1.0%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
The way that farmers use pest management technologies does not really impact the rate at which resistance evolves (Note that this question is the reverse of its coordinating question in the AFRI survey)	26.3%	40.6%	18.3%	11.7%	3.1%
	Strongly Disagree	Somewhat Disagree	Neither	Somewhat Agree	Strongly Agree
Poor management by a few farmers leads to premature evolution of resistant pests	1.7%	7.7%	21.7%	45.0%	23.8%

CONCLUSIONS

Significance and Future Considerations

INTRODUCTION

In research on the herbicide resistance issue, social aspects have been largely ignored. The focus has instead been on 'natural' aspects including weed biology that are considered 'outside' of society. Sociology as a discipline could contribute much to the understanding of weed management and other problems associated with conventional farming systems in the United States by considering society and agriculture in conjoint constitution with the environment and related sustainability (Dunlap and Martin 1983; Foster 2002). In my dissertation I contributed to this research directive in a mixed methods study. I explored issues of framing, attachment, and what drives farmers' attitudes and practices related to weed management on their farm.

I focused specifically on farmers' resistance to Integrated Weed Management methods and continued reliance on herbicide-only weed management plans. Herbicide resistance thus served as an 'indicator case,' reflecting a larger sociotechnical imaginary in US agriculture that focuses on technological, often chemical, solutions to various problems and eschews community-based approaches. The framing and attachment of farmers are, in turn, impacted by biophysical place characteristics and the structure of conventional agriculture in the US, iteratively influencing the options available to farmers – i.e. their agency of choice. Although IWM is promoted and education programs are offered, growers do not necessarily choose to adopt best management practices (BMPs) *despite understanding their benefits* (Binimelis et al. 2009; Carolan and Stuart 2015; Johnson et al. 2009). The socio-ecological factors underlying this reluctance to BMP adoption are unclear – discovering how the dual elements of nature and society contribute to this reluctance was the focus of my dissertation.

The overarching research goal for my dissertation was to investigate how US farmers conceptualize and manage herbicide resistance as an example of how sociology can contribute to an improved understanding of the social, cultural and environmental dimensions of US and global agriculture. In addition, I demonstrated how these issues might be more effectively studied. In order to achieve this goal, I broke my dissertation into three chapters, each with specific objectives that aided in addressing my larger research goal. For each of these chapters the data came from a mixed methods study on farmers' herbicide resistant weed perspectives and management. As part of a research team funded by the Agriculture and Food Research Initiative, I gathered focus group and survey data from conventional corn and soybean growers across the US.

My first chapter addressed how farmers' cognitive framing of herbicide resistance interacts with a larger agricultural sociotechnical imaginary to impact weed management behaviors, helping to bridge cognitive and cultural reasons for different types of management. Chapter 2 introduced a spatial understanding to the issue, investigating how herbicide resistant weeds act upon the farmers' whose fields they infest. These two chapters act to cover structural, agential, and spatial components of farmers' herbicide resistance management, drawing a more complete picture of the conjoint constitution underlying weed management and other problems of US conventional agriculture. My final chapter acted as a guide to future researchers interested in this topic. Structural, agential, and spatial components are important but not the only predictors of herbicide resistance management. If we are to fully understand the problem, further research – for instance how chemical and seed agents influence farmers' decision-making –

needs to be conducted. Chapter 3 addressed issues associated with researching farmers and suggests a theoretical grounding for mixed methods that can be used to expand this and other fields of study.

The above three chapters were written with the intention of contributing to the sociological discipline. Firstly, my dissertation improved the understanding of why people, and specifically farmers, make certain behavioral/managerial decisions. Specifically, Chapter 1 gave insight into structural binds and how farmers make meaning of their as-if trust in herbicides through the application of a techno-optimism master frame. Chapter 2 further delved into issues of decision-making, looking at how herbicide resistant weeds act as a place disruption and constrain farmers' interpretations and management practices. Relatedly, Chapter 2 helped clarify how affective dimensions of place impact nature-related attitudes and behaviors –supporting the notion that place attachment is filtered through interpretive schemes to impact outcomes in attitudes and behaviors (e.g. Scannell and Gifford 2010). Finally, I contributed a theoretical rationale for mixed methods research based on relational pragmatism that will be useful for future sociological research projects.

In addition to these contributions to sociology, my dissertation makes several practical contributions useful in agricultural policy and education. In particular, my findings address how we might better advance sustainable agriculture through the understanding of farmers' framing and place attachments. This understanding of farmers' decision making processes will aid in the formation of programs and policies geared at developing a sustainable agricultural system.

In this concluding chapter, I provide an overview of the outcomes from each of my chapters. Within each of these, I discuss the impact my research has on sociology and other relevant disciplines. Finally, I draw broader conclusions connecting the three chapters and addressing my broader research question; how US farmers conceptualize and deal with herbicide resistance and how these issues might be more effectively studied.

CHAPTER 1

The first chapter of my dissertation addressed how farmers make meaning of their continued use of herbicide-dependent weed management programs through cognitive framing and cultural repertoires. To reach this goal, I drew on the concepts of sociotechnical imaginaries and master frames. Within US agriculture, I describe a sociotechnical imaginary of productivism in which the envisioned 'good' agricultural society produces large quantities of crops for food, fuel, etc. through the application of modern technologies and economies of scale. This sociotechnical imaginary is, I argue, both producing and reinforcing a techno-optimism master frame that farmers draw upon to explain their herbicide resistant weed management beliefs and actions. This interaction of sociotechnical imaginaries and master frames aids in understanding the processes of trust and meaning-making that farmers are going through when they a) express hope or faith in new herbicide development and b) continue to use an herbicide-only management plan despite knowing better.

In questioning why farmers express trust in and reliance on herbicides to combat weed resistance even though they understand the benefits of IWM (Binimelis et al. 2009; Johnson et al. 2009; Webster and Sosnoskie 2010), I gathered evidence that this trust is actually an 'as-if' trust that farmers express due to their situation of dependence. In essence, farmers resist adopting IWM because they have been convinced that it is not feasible by the sociotechnical imaginary of agriculture and the structural necessities of surviving in the US conventional agriculture system. Herbicides are seen as the only realistic choice. This produces statements of trust that are not active in nature, but rather disguise feelings of dependency and a lack of agency.

Searching for evidence to validate their obligatory trust and continued reliance on herbicides, growers in our focus groups drew on a techno-optimism master frame that they aligned with the goals and ideals of the US agriculture sociotechnical imaginary. This master frame resonated well with growers due to its narrative fidelity with the sociotechnical imaginary, as well as their experiential commensurability with its claims. This helps explain other studies (i.e. Bonny 2016; Dentzman et al. 2016; Llewellyn et al. 2004) which have found that farmers tend to have high faith in herbicide management plans, but see a decrease in this faith when they experience herbicide resistance on their own farm.

My findings in this chapter contribute in several ways to my overarching research goal of investigating how US farmers conceptualize and deal with herbicide resistance. Firstly, I demonstrate that farmers draw on a techno-optimism master frame to explain their faith in herbicide development, herbicides' ability to control natural processes, and continued reliance on such herbicides. This is a fundamental part of how farmers think about herbicide resistance. However, I also discovered that this techno-optimism is often being drawn on to validate not an *active* faith in herbicides but rather an *as-if* trust that farmers feel obligated to express given the structurally limiting conditions of conventional agriculture production systems. Farmers are therefore dealing with the bind that economies of scale place upon them by drawing on a master frame that validates their continued use of herbicides in light of the US agriculture sociotechnical imaginary.

This further broadens a sociological understanding of why people make certain behavioral and managerial decisions. Specifically, my findings emphasize that nature and society need to be considered in conjoint constitution. When looking at herbicide resistance from a strictly chemical or biological standpoint, it makes little sense why farmers express a persistent faith in herbicides and fail to incorporate more integrated management practices. With the integration of a sociological perspective, however, we see that farmers feel trapped by both the biological fact of herbicide resistance and a sociotechnical imaginary espousing synthetic inputs and increasing productivity. Herbicide resistance is a whole-systems issue, a problem born of humans and nature in tandem, and farmers' decisions about how to manage herbicide resistance must be considered in the same way.

I additionally contribute to the framing literature by applying the notions of sociotechnical imaginaries and as-if trust. By introducing the sociotechnical imaginary of conventional US agriculture, I clarify how a techno-optimism master frame maintains narrative fidelity with farmers who are increasingly experiencing the challenge of herbicide resistance. Additionally, I show how a master frame can be drawn upon to validate beliefs and actions that are not rooted in a deep faith or moral conviction, but rather the product of structural and ideological constraints that produce a dependent as-if trust.

Finally, my findings lead to several suggestions for the future of weed management in conventional US farming systems. Given that farmers feel trapped in an herbicide management plan, they need to be presented with alternatives that feel feasible to them. Through processes of extension, field days, and other forms of education, frame dissonance can be nurtured and alternatives to an obligatory trust in herbicides proffered. The less farmers feel trapped in an herbicide management plan, the more likely they are to question their as-if trust and begin acknowledging feelings of frame dissonance. Although techno-optimism seems unlikely to go into abeyance due to its strong narrative fidelity with the sociotechnical imaginary of US agriculture, it is possible that this master frame could be used to encourage IWM practices. If IWM is presented as a technological innovation capable of preserving the effectiveness of herbicides, it is more likely to be accepted than if it is framed as a movement away from technological solutions. Fostering farmers' techno-optimistic diagnosis of the cause of herbicide resistance – i.e. poor management – may also be useful if IWM can be framed as good management while herbicide-only management is framed as poor. In this way the diagnosis framing that farmers already employ can be used to encourage an alteration in their prognosis framing – herbicides may be *part* of the answer, but proper management through IWM technology is also necessary.

This chapter's analysis of farmers' framing of herbicide resistance suggests the need for a deeper consideration of how the presence of herbicide resistant weeds influences farmers' beliefs and practices. Specifically, the findings of this chapter suggest that when farmers experience herbicide resistance on or near their farm, their experiential commensurability with a techno-optimism master frame is challenged. This may result in some frame dissonance leading them to question the utility of an herbicide dependent weed management plan. In my second chapter, I further investigate how the presence of herbicide resistant weeds guides farmers' adherence to various interpretations of the herbicide resistance issue and subsequent management practices.

CHAPTER 2

According to some studies, farmers who have a greater density of herbicide resistant weeds on their farm engage in more diverse weed management approaches (e.g. Livingston et al. 2015; Llewellyn, Lindner, Pannell and Powles 2004). For instance Bonny (2016) found that farmers whose farms were already infested with herbicide resistant weeds were more likely to use IWM strategies than those without weed resistance. This matches with theories of experiential commensurability covered in the first chapter of my dissertation. In my second chapter, I expanded this to explore a range of place attachment dimensions to help understand the processes of attachment that farmers are going through when they experience place disruption in the form of herbicide resistance. In clarifying this relationship, my primary research goal was to discover whether HR weed disruption increases place attachment, and if so whether it has an influence on a) farmers' interpretation of HR weeds and b) actual weed management behaviors.

Based on my preliminary reading of the place literature, I aimed to answer four main queries that contribute to my main research goal. These were; *1*) Can farmers' place attachment can be broken into biophysical, community, identity, dependence, and family dimensions? *2*) How does the presence of place-disruptive herbicide resistant weeds impact farmers' place attachment?, *3*) Do dimensions of farmers' place attachment impact their interpretation and management of herbicide resistant weeds?, and *4*) How will direct effect and disruption models of place attachment perform in relation to herbicide resistance management?

Working with survey data from conventional corn and soybean farmers across the US, I found that farmers expressed attachment to their farm in a holistic form that was only separable from community-based attachment. This supports arguments that breaking place attachment into multiple smaller dimensions is unnecessary – or at least that it should not be done arbitrarily

(Williams and Stewart 1998). Therefore my first query is answered in the negative – farmers' place attachment cannot be broken down into multiple dimensions, but rather diverges along lines of place attachment and non-place-based community attachment.

Looking at my second query, I found that both holistic farm attachment and community attachment were increased by the presence of herbicide resistant Palmer amaranth on farmers' land. This indicates that herbicide resistance *does* constitute a place disruption that triggers latent feelings of attachment. In answer to my third query, I also discovered that this increased attachment has several impacts on how farmers interpret herbicide resistance.

In reference to my final query, I found that the place disruption model out-performed a simplistic direct effects model, and was a good fit for explaining herbicide resistance as a place disruption. Specifically, herbicide resistant weeds increased place and community attachment which in turn influenced how farmers interpret the issue of herbicide resistance. These interpretations, along with neighborly communication, affect some but not all of farmers' weed management practices.

My findings in this chapter contribute in several ways to my overarching research goal of investigating how US farmers conceptualize and manage herbicide resistance. In particular, I help explain why some studies (e.g. Bonny 2016) have found that farmers with more herbicide resistant weeds *on their farm* tend to use a greater variety of IWM practices. The physical reality of these weeds force farmers to consider their own attachment to their farm and community – they are a disruption that challenges place distinctiveness, the self-efficacy of farmers, farmers' control over their farmland, and the continuity of the farm through future generations (Anton and Lawrence 2016; Devine-Wright 2009). When forced to confront these disruptive realities, farmers' attachments are triggered. This leads to differing interpretations of the herbicide resistance issue.

As far as management outcomes, I show that community attachment increases farmers' interpretation of HR weeds as an issue to be solved through technological innovation, which in turn results in a higher intensity of herbicide use. This has some interesting connotations when considered in tandem with findings on techno-optimism from my first chapter. In that chapter, I discovered that techno-optimism is often an as-if trust farmers feel forced to adopt due to structural constraints. Therefore we see that increased community attachment due to the presence of HR weeds increases farmers' *reported* techno-optimism, which may in fact constitute a false trust that farmers feel forced into due to the threat of HR weeds on their farm. This techno-optimism, in my place disruption model, was shown to increase the intensity with which farmers apply herbicides. Thus my first two chapters, when considered together, demonstrate how farmers feel threatened by HR weeds on their own farms, and how this threat increases feelings of obligatory trust in herbicides and actual use of these herbicides through community-based, non-farm attachment.

Although this pattern is reason for some concern, my place disruption model also shows a second management outcome that demonstrates how IWM may be increased. Increased place and community attachments increase a concern interpretation, which in turn causes farmers to be more communicative with neighboring farmers. This communication and community participation has a positive impact on both farmers' simple and complex IWM strategies. Thus we see that HR weeds increase attachment, which can facilitate both a concern interpretation and a techno-optimism interpretation. The former leads to better communication and more IWM use, while the latter constitutes as as-if trust that leads to more intense herbicide use. Therefore increasing IWM use may involve encouraging farmers' interpretations of concern and interaction with neighbors over a techno-optimism interpretation.

My findings help to verify the utility of Mihaylov and Perkins' (2004) place disruption model, which was in turn based on Devine Wright's (2009) five stages of reaction to place change. This also supports Scannell and Gifford's (2010b) hypothesis that attachment will result in differing environmental management practices depending on the dominant *interpretation* of environmental disturbances. This also contributes to sociology by expanding our understanding of how the physical environment is tied irrevocably to societal interpretations and management practices – sometimes creating conflicting interpretations and management practices. This addresses Dunlap and Martin's (1983) call for an increased consideration of natural variables within sociology, as well as Freudenburg, Frickel and Gramling's (1995) exhortation to consider nature and society as inseparably intertwined.

These findings also point to several ways to help farmers move towards a more sustainable integrated weed management plan. First, it will be important to educate farmers on the likelihood of new herbicide development and new technological solutions. A new herbicide mode of action has not been discovered for over 20 years (Duke 2011; Livingston et al. 2015; Harker et al. 2012) and is not expected in the near future. If farmers recognize this, it may help to decrease a techno-optimism interpretation and challenge their as-if trust. Additionally, it could increase concern and associated neighborly communication and IWM practices.

Relatedly, there needs to be a focus on increasing farmers' interactions with their neighbors and other farmers. Although my model showed that neighboring interaction aids in adopting complex IWM practices, the survey also reported that nearly 45% of farmers have *never* discussed herbicide resistance with their neighbors. This is corroborated by findings from

Dentzman and Jussaume (forthcoming). In their focus groups of corn and soybean growers, they found that growers were very reticent to discuss weed management with neighbors as it contrasted with their ideologies on farmers' individualism and autonomy. These findings demonstrate that farmers have some difficulty or reticence to communicate with their neighbors and other farmers about herbicide resistance – however when they do so it has serious benefits in terms of IWM usage. Programming that builds on the concern triggered by place disruption may help bring growers together for these necessary discussions.

My findings demonstrate the complex nature of the herbicide resistance issue. We were able to get at this complexity through an exploratory mixed methods design, allowing us to collect detailed information and generate hypotheses as well as test hypotheses and causal chains statistically. Given the extremely complex nature of herbicide resistance and other agricultural issues, research needs to continue in this vein. In the final chapter of my dissertation, I outline a theoretical framework for conducting mixed methods research especially as it relates to the US farming population. My aim is to increase the quality of data collected on the US farming population so as to better understand complex management issue that impact agricultural sustainability. Ideally, my framework will also be applicable to other areas of research and their data collection.

CHAPTER 3

Researching farmers is vital to the future sustainability of agriculture. However, it has become increasingly difficult, especially given low survey response rates among farmers (Pennings et al. 2002). This is true not only of the US farming population – many groups in the US have become 'over-surveyed'. However, I was still able to obtain high quality data on farmers' herbicide resistance through the combination of focus groups and surveys. In the final chapter of my dissertation, I ask how mixed methods can be best employed to facilitate high quality data collection. To explore this, I use my experiences collecting data on farmers and herbicide resistance as a case study to probe the utility of an exploratory mixed methods design for researching farmers in the US. This provides evidence of how a mixed methods approach can help researchers collect better data on a variety of populations, addressing the shortcomings of quantitative and qualitative methods to collect higher quality information from respondents.

Additionally, I have developed a theoretical framework guiding the *creation* and *implementation* of mixed methods – expanding on the more common development of theory related to the *justification* of mixed methods. Combining the perspectives of pragmatism and relationalism, I advocate for a relational pragmatic approach to conducting mixed methods research. This approach is founded on building new relationships and drawing on existing relationships with significant persons – as well as building mutually beneficial relationships with the individuals that are being studied. These relationships help define the realistic, that is pragmatic, ways in which to choose and implement a mixed methods study.

Based on this theoretical grounding and an associated case study of US farmers' perspectives on herbicide resistant weeds, I developed a relational pragmatism framework intended to guide the development and implementation of mixed methods. This framework has the following five principles:

6) Identify team members' pre-existing relationships with significant actors in the area of study
7) Identify how the population of interest relates to the position of team members and other significant actors (both human and non-human)
8) Choose your methods based on the research goals and pragmatic relationships of the researchers and participants.
9) Draw upon pre-existing relationships to facilitate the development and conduct of different methods portions
10) Develop mutually beneficial relationships with participants and other significant actors throughout the process in order to best facilitate a) participant engagement and actionable outcomes and b) effective data collection.

These principles are not a step-by-step list so much as an iterative process of research in which relations are constantly in flux and affect the next step of research development and data collection in a non-linear way. In order to further explicate this process and the utility of a relational pragmatic approach to conducting mixed methods, I used my research farmers' herbicide resistant weed control as a case study. In particular I looked at how our research team drew on relations and the principles outlined above to accomplish our research goals.

Overall, relational pragmatism worked very well as a theoretical framework for the development and implementation of our exploratory mixed methods study. Not only did it facilitate the choice and conduct of the focus groups, but aided in the transformation of the focus groups to an internally valid survey instrument and the execution of that instrument. Without the focus groups, our research would have ended with the generation of theory, hypotheses, and themes. Obviously this is still extremely valuable – however the *goal* of our research was not only to identify these elements, but also to test their viability and impact on farmers' actual weed management practices. In this sense, the survey supplemented the focus groups with the testing of theories and hypotheses, as well as the refinement of themes into multiple factors. Particularly for an interdisciplinary team of researchers, this theoretical framework proved very successful – we would have been able to conclude much less from each method alone.

In addition to the pragmatic utility aimed at best accomplishing our research goals, using focus groups and surveys in an exploratory methodology were pragmatic in the sense that our team's existing relationships with significant actors encouraged and facilitated their use. Our case study thus used the guiding principles of relational pragmatism to enhance the viability of an exploratory mixed methods research approach – enabling the best methods combination for addressing our research goals. For instance, the first principle of relational pragmatism is to "identify team members' pre-existing relationships with significant actors in the area of study". In the case of our research team, our weed scientists had close relationships with extension educators in Iowa, North Carolina, Minnesota and Arkansas. This influenced our perception that focus groups with farmers would be possible, and that they should be conducted in these particular states. Additionally, relationships with farmers and individuals associated with agricultural news outlets provided an avenue to test and advertise a survey. The other four principles were similarly applied to draw on pre-existing and developed relationships, clearly facilitating a more effective data collection procedure.

My findings in this chapter contribute to my overarching research goal of investigating how US farmers conceptualize and manage herbicide resistance – specifically applied to the ‘investigating’ portion. Without the relational pragmatism framework and mixed methods design our research team used, we would have collected much lower quality data. The theories of this chapter therefore laid the foundation for all of the results realized in the two preceding chapters.

Additionally, the theoretical framework laid down in this chapter intertwines two sociological concepts often considered singularly. I emphasize how pragmatism and relationalism can be intertwined to understand the development and application of mixed methods. However, this combination could also be useful in other areas of sociological research. Pragmatism as an ontological commitment argues that philosophical topics should be viewed in terms of practical uses, and that thought is a tool for prediction, problem solving, and action. It focuses on day-to-day social life, social practices, and people’s intertwined activities instead of larger meta-theoretical questions about the structure of reality (Kivinen and Piiroinen 2004). Relationalism can be applied to this ontological stance by considering day-to-day social life and social practices as fundamentally based on transactions between actors within a specific context (Depelteau 2015; Emirbayer 1997). Therefore every act of knowing is the result of a dominant motive (pragmatism), and both the act and motive are essentially relational (Bouwen 2001). This offers sociology a theory of decision-making and action with a distinctly applicable and micro-theoretical bent.

In terms of the paradigmatic debate in mixed methods literature, mixed methods approaches work in practice, even if not always in theory (Firestone 1987; Fuller et. al. 1993; Greene 2008; Wolff et al. 1993). Therefore it may be time to set aside theoretical debates about whether mixed methods are paradigmatically compatible and move towards defining theoretical frameworks for actually *doing* mixed methods. In an attempt to kick start this movement, I developed a theoretical framework, relational pragmatism, intended to guide the development and implementation of mixed methods research. Ideally, I envision my contribution used by other researchers who find this approach useful and test it within their own studies. I also hope to encourage researchers to develop and test their own theoretical frameworks for conducting mixed methods – this is the beginning of a larger theoretical debate about how mixed methods should be done. By comparing and contrasting different theoretical approaches, we can engender a lively and fruitful discussion that will ideally result in the proliferation or consolidation of justifiable ways in which to theoretically ground the practice of mixed methods research.

CONCLUSIONS

The overarching goal of my dissertation has been to investigate how US farmers conceptualize and manage herbicide resistance. I accomplished this through a three-chapter format. From my first chapter I learned how farmers draw on a techno-optimism master frame to validate their as-if trust in the herbicide system. This as-if trust, and the need to ascribe meaning to it, are a product of socio-environmental structural and ontological constraints. Structural constraints, such as natural limitations to farm size and the demands for an economy of scale, limit what weed management strategies are seen as feasible. Similarly, ontological constraints such as the sociotechnical imaginary of US conventional agriculture showcase nature as essentially conquerable by technological innovation. Faced with these binds, farmers see herbicides as the only plausible weed management technique and draw on a techno-optimism master frame to make meaning of their non-optional faith in herbicides.

My second chapter builds on these findings, as I learned how the presence of herbicide resistant weeds influences farmers' as-if trust in herbicides and associated use of these herbicides. Specifically, I found that the presence of herbicide resistant weeds triggers farmers' feelings of place and community attachment. Community attachment then increases a techno-optimism interpretation, which results in a higher intensity use of herbicidal weed control methods. From my first chapter, we are aware that this techno-optimism interpretation is likely to be an as-if trust in herbicides. From this, we can collate the two chapters to describe how the imminent disruption of herbicide resistant weeds causes farmers to think in ways that might otherwise remain latent. This triggered attachment is then funneled into a stronger adherence to an as-if trust in technological solutions to herbicide resistance.

However, this is only one path that the triggered attachments can take. The other is to an increased concern interpretation – i.e. having herbicide resistant weeds on their farm makes farmers more attached to both their farm and community and more liable to recognize herbicide resistance as a very serious problem. This concern then prompts farmers to communicate more with other farmers – i.e. neighbors and growers in their community. Perhaps the most interesting element of this is that this communication results in the increases of basic and complex IWM. This can be paralleled with my first chapter's findings on experiential commensurability. In focus groups where participants had directly dealt with herbicide resistant weeds, there tended to be more frame dissonance. There was a challenging of the techno-optimism master frame, because farmers were no longer experiencing weed management situations that aligned with it. This can be compared to farmers' increased concern in my second chapter – dissonance and concern based on the presence of HR weeds provides an opportunity to promote IWM development. However, my second chapter also emphasizes that farmers need to actively *see* the weeds and *experience* them on their own farm. Herbicide resistant weed infestation at the state level had no impact on attachment in my place disruption model.

I was able to arrive at the above conclusions due to an implementation of mixed methods data collection that was the foundation of my third chapter. In essence, this methodological framework is the cornerstone on which my first and second chapters were built, as well as the cornerstone from which future research can proceed. The basis for my first chapter was the focus groups conducted at the beginning of our exploratory mixed methods design. Given that we knew little about farmers' perspectives on herbicide resistant weeds, focus groups allowed us to uncover how farmers frame this issue in discussion to explain their views and practices both to themselves and others. This led us to develop a survey geared towards issues of techno-optimism and experiential familiarity with herbicide resistant weeds. The survey data then allowed us to test hypotheses about how direct interaction with herbicide resistant weeds affectsd farmers' interpretation of the herbicide resistance issue and subsequent management practices.

While demonstrating the utility of an exploratory mixed methods design for my particular research goals, my third chapter also developed a relational pragmatism framework for the development and implementation of these methods. Drawing on pre-existing and developing relationships between the research team and significant others, we were able to choose, design, and effectively implement focus groups and surveys in an exploratory format. Thus from my third chapter I learned about the usefulness of exploratory mixed methods for my research as well as how relational pragmatism can be used to facilitate these methods in an agricultural setting.

The big takeaway from my three chapters is that farmers' perspectives on, and management of, herbicide resistance is a complex system impacted by conjoint socio-environmental variables that are best studied through relationally pragmatic data collection methods. In terms of my general impact on the field of sociology, I emphasize consideration of inseparable environmental and sociological variables as well as the integration of qualitative and quantitative data collection for a more complete understanding of research problems.

Historically, sociology as a discipline has tended to concentrate on society as divided from 'nature' in order to avoid accusations of environmental determinism (Dunlap and Martin 1983). Similarly, sociology tends to divide along lines of qualitative *versus* quantitative research (Neuman 2003). These divisions are at least partly attributable to a desire on the part of sociologists to be considered scientific by the larger academic and civilian communities. This positivistic bent is a legacy within sociology left by Augustus Comte, often considered the father of both sociology and positivism (Sica 2011). However, as my dissertation shows, these divisions may do more harm than good to the actual quality of research and complex understandings sociology should be pursuing. Although herbicide resistance is just one topic to be studied within agricultural sociology, its position as a touchstone issue of US conventional farming systems locates it as a case study representing the complexity of a multitude of agricultural issues. Similarly, such issues can be expanded to understand non-agricultural aspects of society. While not all sociological research *needs* complex integration of socio-environmental variables and qualitative/quantitative methods, I encourage sociologists to give due consideration to the possibility of addressing these complexities as opposed to focusing on whichever side of the divide they are most familiar with.

In terms of practical outcomes from my dissertation, my findings suggest several ways to promote sustainable agriculture particularly in reference to weed management. Specifically, my findings suggest that growers need to experience herbicide resistant weeds firsthand to challenge their techno-optimistic perspective and promote communication and IWM use. Field days would therefore be a good option, as they give farmers a direct understanding of how herbicide resistant weeds impact a farm. Additionally, they can talk to and learn from the hosting farmers who have directly experienced this issue. This communication may facilitate more IWM implementation before herbicide resistance becomes a direct issue on farmers' own land.

Additionally, farmers' concern and frame dissonance need to be fostered as an alternative to a technology or techno-optimism interpretation of herbicide resistance. One possible avenue to this goal is to work with farmers' attachment to their farmland. Although community attachment increases a technological fixes interpretation, holistic farm attachment does not. Rather, in tandem with community attachment, it promotes a concern interpretation that encourages communication with neighbors and subsequent IWM usage. Unfortunately, such holistic attachment tends not to be triggered unless herbicide resistant weeds are *already* on a farmers' land. As a preventative measure, this obviously falls short. Thus, in addition to field days, education initiatives may be necessary. The techno-optimism master frame needs to be challenged for farmers to experience frame dissonance and challenge their own as-if trust in herbicides. Emphasizing the threat to their own farms, as well as the process of herbicide development, and the fact that it is unlikely to continue indefinitely, may help foster both holistic farm attachment and the frame dissonance necessary to challenge an herbicide-dependent weed management plan.

Of course, it should also be recognized that farmers *are* facing a structurally binding situation in which herbicides present the simplest way to deal with economies of scale and expectations of productivity. It is unfair to ask farmers to adopt IWM practices without also working to address the constraints they face. We need, in short, a revision of the current US conventional agricultural system and the socio-technical imaginary associated with it. This is certainly easier said than done, and specific strategies lie outside the purview of this dissertation. However, I advocate a recognition that farmers are working within a contextually rigid situation and cannot be solely blamed for issues of herbicide resistance *or* expected to solve them on their own. This leads to a call for more research on the structure of agriculture, its sociotechnical imaginary, and how these may be altered for the optimization of sustainability.

Given the complexity of my dissertation's findings, I strongly encourage further research into farmer's perspectives on herbicide resistance and other issues relevant to conventional agriculture. Particularly, more research on the conjoint constitution of such issues is necessary – a goal that is particularly well suited to mixed methods founded in a relational pragmatism framework. Additionally, although I have identified several ways in which farmers think about and explain their weed management practices, I have not empirically determined how these may be employed to encourage a more sustainable agricultural system. Experimentation, especially involving farmer field days, will be necessary to test the utility of these findings for altering farmers' weed management behaviors. Often, the complexity of these issues can seem overwhelming – particularly when they involve individual decisions shaped by structurally binding conditions. However, if we stand a chance of improving the sustainability of the agricultural system in which we find ourselves, we must face this complexity head on – studying it from all angles to gain a better understanding of which approaches will lead to successful changes in the system.

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