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Factors Influencing Farmer Adoption of Soil Health Practices in the United States: a Narrative Review

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Factors influencing farmer adoption of soil health practices in the United States: a narrative review

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Abstract

Soil health practices - such as cover cropping, crop rotation, and conservation tillage - provide synergistic environmental and economic benefits, both on and beyond the farms that utilize them. Given these benefits, researchers are puzzled by the persistent adoption gap for these practices. This narrative review synthesizes the insights of the soil health practices adoption literature, with a focus on US commodity agriculture. While farms, farmers, and farm communities are too heterogeneous to represent with a single model, this review finds five emergent themes: (1) differences in perspective along the adoption continuum, (2) interaction among soil health practices, (3) qualitatively different pathways to incremental and transformative change, (4) non-economic farmer motives, and (5) the key role of larger farm and food system context. This study finds rational actor models inadequate to explain farmer decision-making, suggesting that researchers would do well to utilize interpretive frames that elucidate interactions among groups of people and take account of multiple forms of capital. Reviewing recommendations for increasing the adoption of soil health practices, this study finds that a complementary approach -- combining education, research, policy, measures to overcome

equipment barriers, and efforts to address farm and food system context -- holds the most promise.

Keywords:Sustainable agriculture; soil health; cover crops; conservation tillage; crop rotation

Introduction

Soil health practices - such as cover cropping, crop rotation, and conservation tillage - provide synergistic environmental and economic benefits, both on and beyond the farms where these practices are adopted. For example, cover crops -- nonharvested crops planted in the offseason to improve soil health -- offer large-scale environmental benefits by sequestering carbon, reducing soil erosion, preventing nutrient leaching, and providing habitat for beneficial insects and pollinators, but they can also benefit farmers by boosting soil productivity and subsequent crop yields, suppressing weeds, reducing fertilizer needs, and improving nutrient cycling (Bergtold et al. 2012; CTIC 2015; Gaudin et al. 2013; Long, Ketterings, and Czymmek 2014; Miller, Chin, and Zook 2012; NWF 2012; Poeplau and Don 2015) Similarly, conservation tillage -- any method of tillage that leaves residue from the previous crop on the field -- reduces erosion, while also boosting soil productivity and often lowering farmers' labor and diesel costs (Fuglie 1999; Uri 1997); crop rotation promotes ecological diversity as well as economic diversity, which can help protect farmers against volatility in both climatic and market terms (Carlisle 2015). Given these well-established economic and environmental benefits, researchers have been puzzled by the persistent adoption gap for these practices in US commodity agriculture (Atwell, Schulte, and Westphal 2009; Canales 2015; Long, Ketterings, and Czymmek

2014; Miller, Chin, and Zook 2012; NWF 2012; Sackett 2013; Singer 2008, Snapp et al. 2005; Tosakana et al. 2010). Just 12% of Iowa producers use cover crops (Arbuckle 2012), while only 21% of US corn acreage is managed with zero tillage, known to farmers as no-till (Canales 2015). Multiple studies have attempted to shed more light on why farmers do or do not use soil health practices, in an attempt to better understand and eliminate this adoption gap. The following narrative review synthesizes the insights of the soil health practice adoption literature, with a focus on US commodity agriculture.

There is an extensive literature on the adoption and diffusion of agricultural innovations, and numerous studies focus specifically on the adoption of best management practices (BMPs), sustainable agriculture (SA), or conservation agriculture (CA). While a great many factors have been identified as potentially important to adoption, meta-analyses of the adoption literature find no universally correlated variables and no successfully predictive models. Instead, a key finding of this literature is that farms, farmers, and farm communities are quite heterogeneous, and accordingly, that efforts to increase adoption of soil health practices should be locally specific (Knowler and Bradshaw 2007; Prokopy et al. 2008). Thus, rather than trying to develop a hierarchy of most to least important factors or a predictive model, this review aims to provide policymakers and technical assistance personnel with a starting point: factors that should be investigated as potentially important to the adoption or non-adoption of practices, factors that may interact with one another, interpretive frames that can elucidate farmer decision-making, and promising potential interventions that may increase adoption.

Methods

Below, I present a narrative review of the US soil health practices adoption literature, Most reviewed studies focus on commodity grain agriculture, given that this sector demonstrates a sizable adoption gap, and that greater adoption could have significant environmental benefits. Multiple soil health practices are represented in these studies, but this review intentionally emphasizes cover cropping, conservation tillage, and crop rotation - practices with synergistic economic and environmental benefits that are well-studied, impactful, and of interest to policymakers and researchers. Overall, this review synthesizes 43 independent studies. Of these, 33 are surveys, and the remaining 10 studies utilize ethnography, focus groups, interviews with project collaborators, or historical analysis. Row crop systems are the focus of 28 studies, and 24 of the studies were conducted in the US Midwest. About half are single practice studies of cover crop (16) or conservation tillage (6) adoption, while the rest cover multiple conservation practices. Given that policy and attitudes regarding soil health practices have changed markedly over the course of the past half century, this review focuses on relatively recent studies: 18 of the studies were conducted in the past five years, 27 in the past 10 years, and 34 within the past 15 years. The oldest reviewed study was published in 1989. I also interviewed three key individuals engaged in trying to increase adoption of soil health practices, both to add qualitative perspective and ensure I identified relevant literature. The body of the paper consists of a narrative review of motivations for and barriers to adoption highlighted by this literature, incorporating qualitative data and theoretical models useful to interpretation of quantitative results, as well as a review of recommendations and suggestions relevant to researchers, policymakers, and other soil health practice promoters. I also present summary charts (Table 1, Table 2) of factors found to increase or decrease adoption of the most frequently studied soil health practices, conservation tillage and cover cropping. The advantage of this narrative review approach is the ability to integrate insights from studies with different methods and synthesize interpretive findings as well as survey results.

Findings

Factors found to influence soil health practice adoption

Agronomic factors

Agronomic benefits

Farmers' most commonly cited motivations for adopting soil health practices were agronomic, and focused on building long-term soil health. Numerous studies found that both adopters and non-adopters saw the greatest benefits of these practices in terms of their potential to build soil organic matter, reduce erosion, control weeds, and reduce soil compaction (Bergtold et al. 2012; Mine et al. 2014; Sackett 2013; Singer, Nusser, and Alf 2007; Stivers-Young and Tucker 1999). More recent studies also emphasized the management of herbicide-resistant weeds (Arbuckle and Lasley 2013) and capture of nutrients (CTIC 2013, 2014, 2015; Long, Ketterings, and Czymmek 2014), perhaps because of heightened concern about nitrate pollution. Ryan Stockwell, a farmer and nonprofit program manager who works with potential adopters, commented that one of his most successful approaches has been to emphasize the way in which soil health practices like cover cropping can solve farmers' existing agronomic problems (personal communication, August 12, 2015). Survey responses indicate that farmers' concerns

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have evolved from a focus on soil erosion (in the 1980s and early 1990s) toward greater concern with overall soil health and soil organic matter, as well as nutrient leaching.

Agronomic barriers

Agronomic matters were also the most frequently cited barriers to farmer adoption of soil health practices, particularly cover cropping. Chief among agronomic barriers were those connected to interference with cash crops, typically expressed as difficulty fitting soil health practices into short and unpredictable growing seasons (Bergtold et al. 2012; CTIC 2014, 2015; Long, Ketterings, and Czymmek 2013; Mallory, Posner, and Baldock 1998; Miller, Chin, and Zook 2012; Stivers-Young and Tucker 1999). Many farmers expressed concern that cover crops might interfere with their fall harvest or spring planting, and several cited proper termination and incorporation of cover crops as a challenge (CTIC 2014; Miller, Chin, and Zook 2012; Snapp et al. 2005; Stivers-Young and Tucker 1999). Arbuckle (2012) found that such concerns were more pronounced for larger farmers, those growing corn or soybeans, and those with less knowledge of cover crops. Other agronomic barriers specific to cover crops were difficulty with establishment or germination and the concern that cover crops could deplete soil moisture needed for a cash crop (CTIC 2013, 2014, 2015; Sackett 2013).

Financial factors

Financial benefits

Multiple studies found that immediate financial benefits were less important to farmers than long-term soil health (Bergtold, Fewell, and Duffy 2010; CTIC 2013; Miller, Chin, and Zook

2012). This was particularly true for farmers who had already adopted soil health practices (CTIC 2015). Non-adopters, however, were more interested in potential yield benefits to cash crops (CTIC 2015), and when viewed in context, farmers' responses about financial dimensions indicated an integrated understanding of agronomic and economic benefits. For example, one study found that respondents who agreed that profits from no-till were equal to or greater than those from other tillage systems were more likely to adopt the practice (Baradi 2009). Another found farmers agreeing with the statement, "reducing soil erosion makes economic sense for my farm" (Ryan 2003). Yield benefits to cash crops weren't the only way in which soil health practices boosted farmers' bottom line. One study of cover crop users found that a majority of vegetable and horticultural producers were able to reduce fertility needs (CTIC 2015), and studies of crop rotation found that this practice improved farmers' economic resilience (Carlisle 2015)

Financial barriers

The costs associated with some soil health practices are clearly a significant barrier to their adoption. Researchers identified three types of costs - opportunity costs associated with cash crop interference, initial investment in equipment or infrastructure, and ongoing investment in seed, labor, and management - finding that all three could act alone or in concert to discourage farmers from using soil health practices. Opportunity costs were clearly the most important barrier (Snapp et al. 2005). Few farmers would consider planting a cover crop in place of a cash crop, unless they had a particularly poor area of land needing amelioration, and even the possibility or perception of interference with a cash crop was enough to dissuade farmers from experimenting with a practice. Equipment barriers were important for both cover crops and crop rotation (Carlisle 2015; CTIC 2015; Snapp et al. 2005). Technologies tend to be adopted more readily when farmers can quickly and easily test them on part of their land (Mine et al. 2014; NWF 2012). But since many farmers lack access to the specialized equipment they would need to plant cover crops, this prevents them from conducting low-investment experiments with the practice (NWF 2012). Arbuckle (2012) found that 40% of Iowa farmers lacked the equipment necessary for cover cropping, and an Iowa farmer quoted in a nonprofit newsletter explained that it's difficult for farmers to lengthen their rotations to include small grains because grain drills (for planting) are expensive, and the slats in a corn bin are too big for a crop like oats (Ohde 2015). Ongoing costs - in seed, labor, and management, also present substantial barriers to adoption. Several studies found that this was, in fact, the most significant barrier cited by farmers (Bergtold, Fewell, and Duffy 2010; CTIC 2014; Mallory, Posner, and Baldock 1998).

Another way in which researchers investigated the significance of financial barriers was by evaluating the significance of farmers' capacity and capital. Although this was not a universal finding, many studies found larger farm size and higher farm returns correlated with greater adoption of soil health practices like no-till and cover cropping (Baradi 2009; Featherstone and Goodwin 1993; Fuglie 1999; Gabrielyan 2010; Upadhyay et al. 2003; Vitale et al. 2011; Westra and Olson 1997). Researchers hypothesized that this was due to these farms' ability to spread initial investments over greater acreage and utilize higher revenues as a cushion against the risk of potential losses. The relationship between farm size and soil health practices was complicated, however, as demonstrated by several studies that delved deeper into this topic. "It is the small farm operator that is more likely to recognize the existence of a soil erosion problem," one researcher found. "In contrast, given the recognition of the problem, it is the larger operators that are more likely to adopt the soil conserving technologies" (Gould et al. 1989, 179). Several studies found that larger farms were more likely to adopt cover crops, but smaller farms planted a greater percentage of their acreage to cover crops (CTIC 2015; Stivers-Young and Tucker 1999), and Arbuckle (2012) found that small-scale farmers associate cover crops with environmental benefits more than larger-scale farmers do. Finally, two studies found that the influence of farm size differed depending on the specific conservation practice (Lambert et al. 2007; Soule, Tegene, and Wiebe 2000). If smaller farmers are often more motivated to adopt soil health practices, but larger famers more able, this points to a potential role for cooperative associations and publicly-supported infrastructure, to remove scale-related barriers.

Land tenure

The soil health practices adoption literature does not arrive at a consistent conclusion with respect to the influence of land tenure on farmers' conservation decisions. While it has been hypothesized that renters are less likely to adopt conservation improvements, and this relationship has been substantiated in some cases (Bergtold et al. 2012; Upadhyay et al. 2003), many other studies find no such correlation. Two studies in the Corn Belt (Carolan 2005; Soule 2001) hypothesized that clearer correlation might be obtained by distinguishing share renters from cash renters; both found that share renters behaved more like owner-operators, while cash renters were less likely to invest in conservation improvements, particularly those with medium-to-long term benefits. Carolan (2005) explains that cash leases are more uncertain and shorter term, and that such insecure tenure impacts conservation decisions in multiple ways. Not only are cash renters more reluctant to make long-term investments in land they may not farm for very long; they are also hesitant to "rock the boat" with landlords by suggesting conservation practices, fearful of jeopardizing their tenancy. Female landlords with a conservation orientation expressed similar anxiety about rocking the boat with leaseholders, fearful of losing their tenants.

Public policy

Supportive policies

Farm Bill conservation programs instituted since 1985 have significantly increased the adoption of soil health practices, particularly conservation tillage and no-till. Numerous studies credited conservation payments, mandatory conservation plans, and resulting contact with the Natural Resource Conservation Service (formerly Soil Conservation Service) with increases in the prevalence of soil conservation practices across the US (Baradi 2009, Coughenour 2003, Fuglie 1999; Ryan, Erickson, and De Young 2003; Soule 2001; Wu and Babcock 1998). One study noted that farmers who participated in conservation programs were more likely to make additional long-term conservation investments (Featherstone and Goodwin 1993). While conservation programs such as the Conservation Reserve Program have been effective in reducing erosion through land retirement and conservation tillage, however, soil health practice promoters Ryan Stockwell and Stefan Gailans noted that cover cropping and crop rotation have been slower to take hold, perhaps because the programs that support these practices are newer, less robustly funded, and not as well absorbed into rural and agency culture (personal communications, August 12, 2015).

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Policy barriers

Interestingly, few studies investigated policy barriers. However, a recent white paper (NWF 2012), which distilled the insights of 36 farmers, scientists, extensionists and policy analysts working to increase cover crop adoption, cited several such barriers. According to this white paper, current Risk Management Agency policy is such that some cover cropping practices may result in the loss of crop insurance coverage - and in other cases, the policy is unclear enough that the potential for insurance loss alone is a deterrent to planting cover crops. This study also found barriers stemming from policy at the Farm Service Agency, which classifies some cover crops as a fruit or vegetable, meaning farmers may forfeit ACRE/DCP payments. Also, cover crops do not count as fallow in the Great Plains, so farmers may lose ACRE/DCP payment in that region. Finally, this study found that cover crops receive a poor rank for the Environmental Quality Incentives Program (EQIP) in some localities, resulting in low eligibility for cost-share.

Cost-share

The influences of existing and potential cost-sharing programs are by far the most studied intersection of policy and farmer adoption of soil health practices. The results of this exhaustive study, however, have been mixed (Arbuckle 2012; CTIC 2015; Ryan, Erickson, and De Young 2003; Singer, Nusser, and Alf 2007). While cost-share appears to have been important in the relatively widespread adoption of conservation tillage (Uri 1999), impacts of the payments themselves are difficult to tease out from the technical assistance and education campaigns that have accompanied them, as well as farmers' intrinsic and agronomic motivations to reduce erosion. More nuanced studies of cost share found that it was more important to interested non-adopters than early adopters (CTIC 2015), and more generally, that its role may be to remove financial barriers for farmers whose primary motivations are non-economic (Arbuckle 2012).

Knowledge and information

Knowledge benefits

Multiple studies found that farmer knowledge and access to information were critical factors influencing adoption of soil health practices (Arbuckle 2012; CTIC 2013, 2014, 2015; Miller, Chin, and Zook 2012; Snapp et al. 2005; Vitale et al. 2011). Farmers who were more knowledgeable about the environmental and agronomic benefits of these practices, and who had confidence in their ability to properly implement them, were significantly more likely to adopt them. Greater knowledge tended to ameliorate other perceived barriers such as local climate conditions or interference with a cash crop (Arbuckle 2012). First-hand experience was perhaps the most effective source of knowledge: once they started using a soil health practice, farmers were likely to continue it (Bergtold, Fewell, and Duffy 2010; Long, Ketterings, and Czymmek 2014; Sackett 2013). Nonetheless, adopters and non-adopters alike expressed a desire for more information about soil health practices (Arbuckle 2012; CTIC 2015), and numerous studies indicate that inadequate access to this information remains a major barrier to adoption.

Knowledge barriers

Farmers experience multiple knowledge barriers with respect to soil health practices (CTIC 2014, 2014, 2015; Drost et al. 1996; Long, Ketterings, and Czymmek 2014; Miller, Chin, and Zook 2012; Singer, Nusser, and Alf 2007; Snapp et al. 2005). Surveyed farmers lacked sufficient information about the benefits of these practices and how to measure them, and many farmers felt underprepared to implement and optimize practices like cover cropping and crop rotation. Farmers were particularly keen for better locally-specific information on matters like cover crop variety selection (Carlisle 2015; Carolan 2005), and many were unaware of cost-share and technical assistance available through Natural Resource Conservation Service programs like the Conservation Stewardship Program (CSP) and EQIP (Miller, Chin, and Zook 2012).

Social networks

Closely tied to questions of knowledge access were questions of social networks. As one researcher put it: "Knowledge is a social relation. Knowledge is people. It ties us to some, often disconnects us from others" (Bell 2004, 15). Indeed, farmers who were better connected to other farmers (and technical assistance providers, agricultural retailers, and researchers) using soil health practices were more likely to adopt them (Carlisle 2015; Coughenour 2003). One study highlighted the key role of "cover crop champions" willing to share their experiences with others, finding that the very presence of early adopters in a given region increased other farmers' access to infrastructure, equipment, and knowledge (NWF 2015). Farmer networks such as the Practical Farmers of Iowa were also important supporters of soil health practice adoption, although soil health practice promoters Ryan Stockwell and Stefan Gailans reflected that such networks were most influential with middle and early adopters prone to accept change (personal communications, August 12, 2015). The power of social networks could cut both ways -- a study of organic farmers found that interaction with organic fertilizer dealers negatively correlated with cover crop adoption (Gabrielyan, Chintawar, and Westra 2010). Hopefully, social networks

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connected to soil health practices were found to be rapidly expanding, to include more "mainstream" and scientifically-oriented actors who have substantial authority as well as large social networks of their own. As one researcher put it, "more people now trust proponents of sustainable agriculture to be speaking the truth" (Carolan 2006, 326**)**.

Community perceptions and aesthetics

Beyond farmers' immediate social networks, the communities in which they lived exercised a great deal of influence on their choice to adopt -- or not adopt -- soil health practices (Bell 2004; Carolan 2005). As Ryan Stockwell reflected (personal communication, August 12, 2015), "people will make grossly economically negligent decisions because it saves them from making a decision that will put them in a nervous or uncomfortable social situation of challenging the status quo." Since neighbors typically evaluated one another's farms visually, farmers were more likely to adopt soil heath practices they considered aesthetically pleasing, which conveyed the message that they were good stewards of their land (Bell 2004; Ryan, Erickson, and De Young 2003). Concerns about maintaining a neat and tidy appearance were particularly pronounced for tenant farmers (Carolan 2005). Unfortunately, in many communities, cover crops are still considered an "oddball" practice (NWF 2012), and benefits like lower rates of soil and nutrient loss, improved soil structure, and beneficial soil organisms are not readily apparent to the passerby (Carolan 2005). However, as concerns proliferate about nutrient pollution of waterways, rural communities may begin to exert pressure in favor of soil health practices (Stefan Gailans, personal communication, August 12, 2015).

Awareness of and concern about the environmental impact of agriculture

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Farmers develop complex mental models about the environmental impact of their practices, and while intrinsic motivations for adopting soil health practices have been understudied, those researchers who did look seriously at them found them to be of key importance (Bell 2004; Bergtold et al. 2012; Carlisle 2015; Gould et al. 1989; Ryan, Erickson, and De Young 2003; Upadhyay et al. 2003; Westra and Olson 1997). A study of Michigan farmers and their adoption of riparian zone conservation practices, such as no-till and woody buffers, found that the highest ranked farmer motivations were "protecting the environment is important to me," "I want to conserve this land for future generations," "I am very attached to this land and want to protect it," and "polluting the stream would harm my downstream neighbors" (Ryan, Erickson, and De Young 2003). A recent study (Reimer and Prokopy 2014) found that off-farm environmental benefits were one of the primary drivers of conservation program participation, and furthermore, that awareness of external environmental benefits characterized the highest adopters of multiple conservation practices. "You have to want to make the change," Stefan Gailans explained, describing farmers with longer rotations as having a "diversity mindset" (personal communication, August 12, 2015). Apparently, US cover crop users also have a "pollinator mindset" -- 28% plant crops specifically to attract pollinators, while 40% routinely consider them when making pest management decisions (CTIC 2015).

Farmland characteristics

In some cases, farmers' environmental awareness was connected to the physical characteristics of their land. Many studies of conservation tillage adoption found that farmers with sloping or highly erodible land were more likely to adopt this practice (Fuglie 1999; Soule, Tegene, and

Wiebe 2000; Wu and Babcock 1998) although researchers could not definitively establish that this was due to the condition of the land itself, and not the resulting requirement that farmers establish a conservation plan to qualify for certain federal programs. Another commonly studied farm characteristic was irrigation. Although its impact on farmer adoption of soil health practices was unclear, and appeared to vary by practice and other factors, some evidence suggests that farmers with irrigation are more likely to adopt cover crops, because they are less worried about depleting soil moisture (Bergtold et al. 2012; Snapp et al. 2005).

Demographic factors

Demographic factors have been widely studied -- and widely dismissed as predictors of soil health practice adoption, with three exceptions.

College education

College education has routinely, though not uniformly, been correlated with adoption of conservation tillage (Fuglie 1999; Soule 2001; Soule, Tegene, and Wiebe 2000; Upadhyay et al. 2003; Wu and Babcock 1998).

Farmer age

Younger farmers adopt soil health practices at higher rates (Drost et al. 1996; Featherstone and Goodwin 1993; Gabrielyan, Chintawar, and Westra 2010; Lambert et al. 2007; Soule, Tegene, and Wiebe 2000; Wu and Babcock 1997) - perhaps because they have longer farming horizons and can benefit more from long-term conservation benefits, perhaps because they are more environmentally oriented, and perhaps because older farmers are more set in their ways and embedded in longstanding community traditions of the right way to farm. One researcher who looked more closely at age differences found that "less experienced and therefore younger farmers are more likely to adopt alternative tillage practices, but it is the older, more experienced farm operators that are more likely to recognize that an erosion problem exists" (Gould 1989, 179).

Gender

Finally, gender exercises a nuanced, critical, and understudied influence on farmer adoption of soil health practices. A recent survey of Iowa farmers found that female respondents had significantly more positive attitudes toward conservation and collaboration than men, but were also less knowledgeable about best management practices and less likely to adopt conservation practices (Druschke and Secchi 2014). This gender gap is important, the authors emphasize, given that women now own a majority of rented farmland in Iowa and own or co-own just under half of all Iowa farmland, while single women own a full fifth of Iowa farmland. Similarly, Carolan (2005) found that female landlords interested in sustainable agriculture felt isolated and lacked access to the technical knowledge networks that were more welcoming to their male counterparts. Insecure about their technical knowledge, these female landlords were reluctant to approach their tenants to discuss conservation practices, worried they might embarrass themselves or worse, lose a good tenant. Gender roles impacted men's farming practices as well. In a longitudinal study of factors influencing Iowa farmers' conversion or non-conversion to sustainable agriculture, Bell (2004) found that farming practices were tightly coupled with the

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social performance of masculinity, which was critical to farmers' identities. Only those farmers who could cultivate a masculinity consonant with sustainable agricultural practices (What Bell terms "dialogic masculinity," open to feedback and lower levels of control) could practicably adopt them.

Making sense of survey data: holistic understanding of farmer decision-making

Perhaps even more insightful than the data collected in previous studies of soil health practice adoption are the interpretive frames researchers have deployed to make sense of this data. Below, I discuss five emergent observations made by multiple researchers in the course of data analysis, before reviewing the models and interpretive frames utilized to explain these dynamics.

Differences in perspective along the adoption continuum

Multiple researchers noted complex differences among early adopters, potential adopters, and non-interested non-adopters (Arbuckle 2012; Carlisle 2015; Carolan 2006; Miller, Chin, and Zook 2012). Clearly, these groups do not share the same motivations for or barriers to adoption of soil health practices. From a policy standpoint, this means that current users of a practice may not be the most reliable source of information on how to encourage their neighbors to adopt. Different policies may be required to achieve the independent objectives of (1) increasing current adopters' use of soil health practices, (2) removing barriers to adoption for those interesting in adopting who have not yet done so, and (3) convincing non-interested non-adopters to change their minds. Most surveys exhibit some degree of response bias -- acknowledged or unacknowledged -- in favor of adopters or likely adopters, so we currently know a lot more about

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adopters of soil health practices than we do about non-adopters. This is difficult to avoid, but points to a promising area for further research. Several studies also highlighted the importance of understanding adoption as a multi-stage, adaptive process, rather than an instantaneous, single-step decision (Carlisle 2015; Coughenour 2003).

Interaction among different conservation practices

Another emergent theme of the soil health practices adoption literature is the interaction among different practices. Multiple studies found that farmers who engaged in one conservation practice were more likely to engage in others (Bergtold et al. 2012; Lichtenberg 2004; Ryan, Erickson, and De Young 2003; Singer, Nusser, and Alf 2007; Upadhyay et al. 2003; Wilson, Howard, and Burnett 2014). In particular, those who rotated crops or had longer rotations were more likely to use other conservation practices (Vitale et al. 2011; Wu and Babcock 1998). Both agronomic and sociological explanations were offered: many rotation crops provide more time for a winter cover crop, management skills associated with one soil health practice can be transferrable to other practices, and use of soil health practices may indicate or even help cultivate a "conservation mindset," which would increase the likelihood of a farmer using other soil health practices.

Incremental versus transformative change: qualitatively different opportunities

Despite the finding that use of one soil health practice was often correlated with the adoption of others, few researchers fully endorsed a "foot in the door" model (Wilson, Howard, and Burnett 2014), in which incremental transition could lead to complete transformation of farming systems.

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Rather, mechanisms and opportunities for incremental and transformative change appeared to be qualitatively different. Incremental change - greater adoption of a single practice, for example - was facilitated by fitting soil health practices into farmers' existing agronomic systems, economic operations, and mental models. Transformative change typically involved a rupture of farmers' mental models - a sudden, disorienting change, often marked by economic stress, periods of ill health, or spiritual doubts - which led farmers to reject previously held common sense and systemically redesign both their farming system and their economic operation (Bell 2004; Carlisle 2015; Carolan 2006).

Non-economic motives

Researchers were surprised by the degree to which farmers appeared to act on non-economic motives, (CTIC 2014, 2015; Miller, Chin, and Zook 2012; Ryan, Erickson, and De Young 2003; Tosakana 2012; Westra and Olson 1997). In general, the role of economic factors appeared to be secondary rather than primary: while economic factors were unlikely to motivate farmer adoption of soil health practices, they could be important in removing barriers. This finding should not be unexpected: perhaps the most fundamental "non-economic" decision made by farmers and ranchers is the decision to farm and ranch in the first place, given the typical rate of return on their labor.

Key role of larger farm and food system context

While most studies of soil health practice adoption are methodologically designed to analyze farms and farmers as discrete units, researchers observed the key role played by farm and food system context in shaping farmers' choices. With markets, research, technical assistance, agricultural financing, policy, and rural culture all structured to serve dominant cash crop systems, farmers found themselves constrained in adopting practices like cover cropping and crop rotation. Farmers looking to add an alternative crop to their rotation faced barriers locating varieties bred to thrive in their region, appropriate technical assistance and equipment, willing agricultural lenders, and markets to sell their crop (Carlisle 2015; Carolan 2005). Those farmers who were able to diversify their operations, to include higher value and shorter season crops, were more likely to use cover crops (Lambert et al. 2007; Lichtenberg 2004; Singer, Nusser, and Alf 2007; Snapp et al. 2005). Researchers lamented that yield-oriented corn breeders have focused on varieties with earlier and earlier planting dates, leaving less and less of a window for a cover crop (Miller, Chin, and Zook 2012). Some researchers saw farm and food system context expressed in the underlying assumptions contained in farmers' statements about soil health practices. "Anywhere that you go you will hear that it isn't the right location for it, that they don't have enough time [in the growing season]," said Ryan Stockwell (personal communication, August 12, 2015). "You have to confront the underlying assumption, which is that it isn't worth the time."

Inadequacy of rational actor models and alternative interpretive frames

The five emergent themes above, as well as the much-bemoaned "inconsistency" in the soil practice adoption literature, demonstrate the inadequacy of rational actor models in explaining farmer decision-making (Carolan 2005; Coughenour 2003). Farmers are densely connected to many other social and economic actors, both within their community and at other points along

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the supply chain. Thus, theories of decision-making that model individual farmers as discrete social units have little explanatory power in the context of farmer adoption of soil health practices. More promising are interpretive frames that seek to elucidate interactions among groups of people.

The innovation-diffusion model

Observing that farmers and ranchers did not appear to be maximizing their income - nor even maximizing more broadly defined utility, rural sociologists began developing alternative models to explain adoption of agricultural practices. Rogers' (1962) innovation-diffusion paradigm, which emphasizes the role of information, risk factors, and decisionmakers' social positions in their communities, has been widely used, and combined with social network theory (Upadhyay et al. 2003). However, this model, which posits that early adopters help diffuse practices more broadly, fails to satisfactorily explain the findings of many studies.

Actor network theory

Coughenour (2003, 300) proposes actor- network theory (Latour 2005) as a more appropriate model, explaining that adopting this perspective broadens the focus of predicting systems change, from the efficacy of the farmer learning a new technique, to the efficacy of multiple rural actors collaborating to produce new farming system "frames." Applying actor-network theory to a study of the adoption of conservation tillage in Kentucky, Coughenour finds that "no-tillage … is a product of new social networks among farmers, cropland, agricultural advisors, company representatives, and agricultural scientists" (281).

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Social fields and multiple forms of capital

Carolan (2005) takes a different approach, drawing on Pierre Bourdieu's theory of practice (Bourdieu 1984) to explain the adoption or non-adoption of sustainable agricultural practices on rented land in Iowa. Two features of Bourdieu's theory are deployed by Carolan: the concept of social fields and the model of capital as taking many forms. Social fields, Carolan explains, "represent the objective, external principles that circumscribe and delimit the boundary conditions for practical action" (391), and are in a state of continual contestation. Thus, social fields take account of social networks, the influence of community perceptions, and farmers' larger food system context, as well as financial, policy, knowledge, and infrastructural barriers. Within this interpretive frame, differences in perspective along the adoption continuum reflect farmers' differing social fields. Incremental change could be understood as change that can occur within existing social fields or though marginal shifts in the boundaries of social fields, while transformative change might involve large-scale restructuring of social fields or the movement of individual farmers from one social field to another.

Bourdieu defines capital broadly, as resources that have exchange value in at least one social context (Carolan 2006). Thus, in addition to the familiar notion of economic capital, social actors might also accumulate and deploy social capital (a social network), cultural capital (assimilation of cultural values evident through "cultured" behavior, "good taste," educational qualifications, etc.), and symbolic capital (status or recognition). Carolan (2006) finds this notion of capital more helpful in explaining farmer decision-making than theories based on economic capital alone, given that, in rural communities, being perceived as a good farmer has

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considerable value, which often overrides immediate financial gain. The interpretive frame of multiple capitals may help explain the prevalence of non-economic motives and Ryan Stockwell's observation that "people will make grossly economically negligent decisions because it saves them from making a decision that will put them in a nervous or uncomfortable social situation of challenging the status quo."

Suggestions and recommendations

While not all reviewed studies included recommendations, many did, emphasizing that increasing farmer adoption of soil health practices would require multiple, complementary approaches and coordinated efforts that link economic incentives for conservation with both community development and local level conservation support networks and personnel (Arbuckle 2012; Atwell, Schulte, and Westphal 2009; CTIC 2014, 2015).

Education

Given the key role of information barriers in preventing adoption of soil health practices, nearly all studies recommended more and better education (Snapp et al. 2005). Researchers stressed that outreach efforts should include a local perspective and peer-to-peer insight (CTIC 2014; Long, Ketterings, and Czymmek 2014), and should engage not just farmers but also the agribusiness networks that provide farmers with inputs and technical assistance (Arbuckle 2012), as well as local governments, water agencies, and watershed organizations (NWF 2012). While education should focus on answering 'what' and 'how' questions, about such matters as selection and management of cover crops, researchers emphasized that education also needed to answer ‘why’ questions, given that farmers who are knowledgeable about the environmental, agronomic, and economic benefits of soil health practices are more likely to adopt them (Miller, Chin, and Zook 2012, NWF 2012; Singer, Nusser, and Alf 2007). Studies recommended targeted outreach to particular groups, including increased outreach to renters and off-farm landowners (Mine et al. 2014; Soule, Tegene, and Wiebe 2000; Tosakana 2010), peer-to-peer conservation networks among women (Carolan 2005; Druschke and Secchi 2014), and tailored communication strategies that address the difference between small and large farmers and adopter and non-adopter audiences (CTIC 2015; Stivers-Young and Tucker 1999). In a recommendation consistent with a social, symbolic, and cultural capital approach, multiple researchers suggested that outreach efforts highlight the growing use of soil health practices by “mainstream” producers and researchers (Bell 2004; Carolan 2005; NWF 2012); Ryan Stockwell (personal communication, August 12, 2015) recommended a similar strategy to normalize soil health practices: a farmer-to-farmer approach, highlighting the way in which “we as farmers have made changes in the past; change is part of our identity.” Above all, studies concluded, educational material should be clear. Stockwell recommended focusing on soil organic matter, making sure farmers’ understand what it is, why it benefits their operation, and how to manage for it, so they might begin to pay attention to it on soil tests. A recent cover crop adoption study recommended that both written and in-person outreach clearly identify the three most important expected benefits of cover crops, address the most common management concerns, target a specific cropping system, feature a local farmer who successfully integrated cover crops into their operation, include a calculator to estimate financial costs and benefits of adoption, and perhaps discuss cover crop seed saving (Miller, Chin, and Zook 2012). Given increasing concern about nutrient pollution of waterways, the nutrient loss-reduction benefits of soil health practices may be an emerging opportunity for outreach efforts (NWF 2012; Singer, Nusser, and Alf 2007)

Research

Multiple studies recommended further research, particularly research that could help farmers address climate and timing barriers - such as developing cover crop varieties adapted to interseeding or late-season growth (Arbuckle 2012; CTIC 2015; Miller, Chin, and Zook 2012; Sackett 2013; Singer 2008; Snapp et al. 2005). Other suggested research priorities included new cover crops and cover crop mixes (Stivers-Young and Tucker 1999), cover crop nutrient release curves (Miller, Chin, and Zook 2012), cover crop establishment options, cover crop cost-benefit analysis, cover crop species selection, environmental impacts of cover crops, and cover crop management practices specific to particular regions, production systems, and rotations (NWF 2012). Multiple authors recommended participatory research with farmer cooperators (Bell 2004; Sackett 2013; Stivers Young and Tucker 1999), and Carolan (2005) noted that support for such research would require addressing inequities in research funding that disadvantage sustainable agriculture.

Overcoming equipment barriers

Recommended strategies for overcoming equipment barriers included increasing the availability of cover crop services provided by trained custom operators (Arbuckle 2012; NWF 2012) and expanding equipment rental opportunities for equipment that farmers are familiar with but don't necessarily own (like no-till drills) through NRCS, local land conservation associations, or soil

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and water conservation districts (NWF 2012). Researchers suggested that the Farm Service Agency should help farmers purchase specialized equipment through bulk discounts and long-term low-interest loans (Miller, Chin, and Zook 2012; NWF 2012), and expressed the view that if custom operators and cooperatives could get help with up-front costs through loan guarantees, cost-sharing, or incentive payments, they could assist early adopters, who could lead the way to increased demand for services and equipment (NWF 2012).

Policy

Multiple studies addressed the potential role of policy in increasing farmer adoption of soil health practices. Researchers encouraged conservation programs to be more flexible, so as to accommodate geographic, economic, and farm-scale differences (Gould et al. 1989) and allow flexible dates for cover crop planting and termination (Miller, Chin, and Zook 2012). They also encouraged policymakers to be more strategic, urging USDA to develop a department-wide task force to promote cover cropping by compiling needed information, addressing policy barriers, and expanding incentives where practical (NWF 2012). Multiple authors took note of farmers' intrinsic motivations, suggesting that conservation policies tap into farmers' desire to be good stewards and do right by their neighbors (Ryan et al 2003), and finding that farmers may identify more with a "people-shed" (a surrounding network of people and farms) than a "watershed" (Atwell, Schulte, and Westphal 2009). However, studies were also generally supportive of cost-share (CTIC 2013, 2015; Lichtenberg 2004), noting that its greatest value may be for farmers who start using soil health practices with incentive programs and keep investing in them with their own funds, as well as growers who periodically take advantage of incentives to defray costs

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(CTIC 2015). In an August 12, 2015 conversation with the author, Stefan Gailans suggested that public cost-share might be supplement by a conservation or cover crop checkoff, similar to a commodity checkoff, that would dedicate a percentage of agricultural profits to increasing adoption of soil health practices. In one study, 70% of surveyed farmers who had not adopted cover crops said a discounted crop insurance premium for using them could influence their decision to incorporate them (CTIC 2015). In a conversation with the author on August 14, 2015, farmer and former civil servant Clay Pope suggested direct conservation payments based on enrolled acres, with three tiers to encourage those who came in at the bottom level to work their way up and reward those who went "the extra mile."

Address cash crop system and larger context

Recommendations stressed that both researchers and policymakers must address barriers associated with farmers' broader farm and food system context (Arbuckle 2012; Long, Ketterings, and Czymmek 2014; Sackett 2013; Singer 2008; Vitale et al. 2011). One of the most common such recommendations was research and promotion of short-season rotation crops, which would not only diversify farmers' rotations, but would also leave more time for a winter annual cover crop. Likewise, research into early harvest corn varieties - with comparable yield to late harvesting varieties - was encouraged. Carolan (2005) suggested greater implementation of crop-share leasing (rather than cash leasing) and measures to address the constraints placed on renters by lending agencies as well as the structure of agricultural markets, government subsidies, and land rental markets.

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Conclusions

Like previous reviews of the soil health adoption literature, this study funds farms, farmers, and farm communities too heterogeneous to represent with a single model. Factors important to farmer decisionmaking differ according to geographic, economic, and social context. However, taken together, this collection of diverse studies reveals five key emergent themes that should be considered by researchers, policymakers, and others interested in increasing the adoption of soil health practices. First, complex differences among early adopters, potential adopters, and non-interested non-adopters suggest that outreach must be carefully targeted to address the distinct needs and interests of these groups. Second, soil health practices often interact, and farmers who engage in one are more likely to engage in others. Third, incremental change, such as adoption of a single practice, is most likely to be facilitated by fitting a new practice into farmers' existing agronomic systems, economic operations, and mental models; while transformative change - redesign of farming systems - typically involves a rupture of those mental models. Fourth, the role of economic factors is frequently secondary rather than primary: farmers often act on non-economic motives, but economic factors can be important in removing barriers. Fifth, farm and food system context is of paramount importance: so long as markets, technical assistance, agricultural financing, policy, and rural culture are structured to serve dominant cash crop systems, farmers are constrained in adopting practices such as cover cropping and crop rotation. This study finds rational actor models inadequate to explain farmer decision-making, suggesting that researchers would do well to utilize interpretive frames that seek to elucidate interactions among groups of people and take account of multiple forms of capital. Reviewing recommendations for increasing the adoption of soil health practices, this study finds that a complementary approach - combining education, research, policy, measures to overcome equipment barriers, and efforts to address farm and food system context - holds the most promise.

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Table 1. Key findings from the cover crop adoption literature

Reference	Region	Study Size	Mean Farm Size (acres)	Crop System	% Adoption	Factors Found to Increase Adoption	Factors Found to Decrease Adoption	Recommendations for Increased Adoption
Arbuckle (2012)	Iowa	1360	n/a	Row	12%	Potential to -decrease erosion, -increase cash crop productivity, -reduce N loss; -knowledge of and experience with cover crops	-fall harvest interference -delays spring planting -shorter season varieties not available - lack of knowledg	-address climate and equipment barriers -increase knowledge and confidence through cooperatives -work with seed dealers, crop advisors -coordinate

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						-cost-share	e and equipment	extension and private efforts
Bergtold et al. (2007)	AL	247	618	Row	51%	- already using conservation tillage - larger farm size	-more farming experience -input costs -risk aversion	-EQIP and CSP should promote sequential adoption of reduced-tillage, followed by cover crops -target incentives to younger farmers already using conservation tillage on medium sized farms

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Bergtold et al. (2012)	AL	301	781	Row	66%	-perceived environmental benefit -irrigation -cash crop is soybeans -no rotation in place -crediting N additions -fertilizing cover crop -careful timing of terminatio	-higher % rented land -more farm experienc e	-educate farmers about environmental benefits -educate landlords about cover cropping -encourage cover crops in conservation plans -recommend leguminous cash crops -educate on proper management

						n		
CTIC (2013)	US	718	421	All	100% - directed at users	Potential to -decrease soil compactio n -decrease erosion -reduce N loss -control weeds -increase yield of following crop	- challenges with establishm ent -time and labor -difficulty selecting appropriat e variety --seed cost	n/a

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CTIC (2014)	US	1924	911	All	75%	Potential to -increase SOM -decrease erosion -increase yield of following crop -decrease soil compaction -control weeds	-time and labor -challenges with establishment -seed cost required -interference with spring planting	- education -outreach to ag retailers
CTIC (2015)	US	1229	n/a	All	84%	Potential to	-challenges	-workshops that highlight

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						-increase SOM -decrease erosion -control weeds -increase yield of following crop	with establishment -seed cost -time and labor required -interference with spring planting	cover crops -free of discounted seed -reduced crop insurance premiums for cover crop users - cost-share
Gabrielyan et al. (2010)	Corn Belt	233	934	Row - organic	54%	-larger farm size	-more farm experience -higher total income	n/a

							-more interaction with organic fertilizer dealers	
Larson et al. (2001)	TN	448	n/a	Cotton	n/a	-risk aversion in reduced-till cotton systems	-risk aversion in conventional till cotton	-subsidize winter legume cover establishment
Long et al. (2014)	NY	115	n/a	Dairy	19%	Potential to -decrease erosion, -increase SOM -reduce N	-lack of time -seed cost -lack of knowledge -	-changes in crop variety selection -farmer-to-farmer exchange of success

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						loss;	challenges with seeding and germination	stories -cost-share

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Maryland Dept. of Ag. (2005)	MD	673	n/a	All	83%	-availability of time and labor -defined rotation or production goals -cost-share -environmental concerns	-restrictive planting or harvesting deadline -low cost share rates -lack of time for planting -seed expense and unavailability	-increase flexibility of cost-share program -disseminate information about program requirements -decrease restrictions on cover crop harvest/sale and manure spreading
Miller et al. (2012)	NC	188	149 media		81%	Potential to -improve	- finding time to plant and	- disseminate information about cover

			n:6			long-term soil quality -boost soil fertility for following cash crop -decrease erosion -control weeds	incorporate cover crop -seed and labor costs -difficulty choosing termination date -difficulty selecting appropriate variety -lack of information	crops, EQIP, and CSP -invest research funds for better varieties and mixes of cover crops that reduce timing barriers, and simple models for their nutrient benefits -increase opportunities for farmer-to-farmer knowledge

								sharing -flexible dates for cover crop planting and termination through CSP, EQIP, others -educate on cover crop seed saving -FSA help farmers finance specialized equipment -encourage cooperative associations among

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								farmers
Mine et. al (2014)	Iowa	212	N/A	Row	23	Potential to - conserve soil - reduce input cost - increase yields	- lack of inputs - confusing regulation	- Fully demonstrate the potential of cover crops to improve yields - Inform landowners currently using crop share and custom leases about the cost-saving benefits of cover crops - Revise Federal Crop

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								Insurance policy to incentivize cover crops
Sackett (2013)	MN	17	365	Row & livestock	100% - cooperators in cover crop extension project	Potential to -decrease erosion -increase SOM -control weeds	-cost -water usage -difficulties with establishment and germination	-research interseeding, aerial seeding, how cover crops increase soil health and decrease erosion -develop early-maturing corn and soy and cold-hardy, fast-germinating

								cover crops - education and outreach
Singer et al. (2007)	Corn Belt	1096	768	Row	18%	Potential to -decrease erosion -increase SOM -crop diversity -knowledge of and experience with cover crops	-management time -input costs -no runoff problem present -use of no-till -lack of information	-incentive payments of $23/acre would induce 50% adoption -education about role of cover crops in reducing nutrient loss

Snapp et al. (2005)	MI	11	2471	Potato	n/a	-aerial interseeding -irrigation	-seed price -inadequate time/labor to incorporate residue -less predictable N release -opportunity cost of replacing cash crop	-establish proven varieties and management practices -provide easy management tools for predicting N replacement -cost-share through farm-programs

Stivers-Young & Tucker (1999)	NY	118	314	Veg.	69%	Potential to -decrease erosion -increase SOM	-interference with spring field work and fall harvest -difficulty in incorporation & plowdown	-further research on improved cover crop varieties, planting practices to minimize interference with fall harvest and spring management -education tailored to farm size

This table presents 16 US studies that focus specifically on cover crops, and describes factors that affected adoption and recommendations to increase adoption (adapted and updated from Miller et al. 2012).

SOM: Soil Organic Matter

Table 2. Key findings from the conservation tillage adoption literature

Reference	Region	Study Size	Mean Farm Size (acres)	Crop System	% Adoption	Factors Found in Increase Adoption	Factors Found to Decrease Adoption	Recommendations for Increased Adoption
Baradi (2009)	KS	135	1629	Row	55%	-larger farm size -perception that no-till is more profitable -familiarity with and participation in conservation programs	n/a	-promote understanding of relative profitability of conservation tillage practices
Fuglie	Corn	142	707	Row	67%	-college	-irrigation	n/a

(1999)	Belt	5				education -more farm experience -larger farm size -conservation plan -off-farm employment -have highly erodible soil		
Gould et al. (1989)	WI	327	181	Row	51%	-perception of need for soil conservatio	-higher age of farmer	- soil conservation programs need to be flexible

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						n -larger farm size	-off-farm work	enough to account for influence of different geographies, economies, operator characteristics
Mine et. al (2014)	Iowa	212	N/A	Row	70%	Potential to - conserve soil - reduce input cost	- Length of time required to realize conservation benefits	- Inform landowners currently using crop share and custom leases about the cost-saving benefits of conservation tillage - Further research into impact on

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								long-term yields

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Ryan et al. (2003)	MI	268	120 (median)	Row	27%	-environmental ethic -attachment to the land -desire to conserve land for future generations -reducing soil erosion makes economic sense for the farm - farmer believes it makes the farm appear well-managed -concern	n/a	Conservation policy should go beyond economic incentives to engage farmers' intrinsic motivation to be good stewards and concern for downstream neighbors

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Upadhyay et al. (2003)	WA	266	3263	Row	40%	-off-farm income -larger farm -education -awareness of erosion control education program - also use other conservation practices	-greater % of rented land	-multiple practice adopters may play a key role as innovators who can influence neighbors
Vitale et al. (2011)	OK	1703	n/a	Row	27%	-younger farmer -larger farm size -crop	-mixed crop-livestock farming -winter	-address needs of crop producers with livestock -find viable

						rotation -knowledge -potential to decrease erosion	wheat monoculture	rotation crops to provide alternatives for winter wheat monoculture

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Westra and Olson (1997)	MN	688	298	Row	61%	-larger farm size -farmer concern about erosion on their land -recent major investment in the farm -use other producers for tillage information -have the management skill for conservation tillage -believe conservation tillage	n/a	n/a

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Wu and Babcock (1998)	NE	539	n/a	Row	31%	-college education -following a conservation plan -sloping land -crop rotation	-more farming experience -irrigation -low quality land	n/a

This table presents 9 relatively recent US studies that focus specifically on conservation tillage, and describes factors that affected adoption and recommendations to increase adoption (adapted from Miller et al. 2012, for cover crop adoption).