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Adoption of agricultural conservation practices in the United States: Evidence from 35 years of quantitative literature

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Abstract: This is a comprehensive review of all published, quantitative studies focused on adoption of agricultural conservation practices in the United States between 1982 and 2017. This review finds that, taken as a whole, few independent variables have a consistent statistically significant relationship with adoption. Analyses showed that variables positively associated with adoption include the farmer self-identifying primarily as stewardship motivated or otherwise nonfinancially motivated, environmental attitudes, a positive attitude toward the particular program or practice, previous adoption of other conservation practices, seeking and using information, awareness of programs or practices, vulnerable land, greater farm size, higher levels of income and formal education, engaging in marketing arrangements, and positive yield impact expected. Some variables often thought to be important, such as land tenure, did not emerge as consistently important in this cross-study review. Other variables, such as farmers' sense of place, training, presence of institutional conditions supporting adoption, and the role of collective decision making are not measured in enough studies to draw conclusions but potentially have a relationship with adoption decisions. Implications for how to promote conservation adoption and directions for future research are discussed. Because positive attitudes and awareness of conservation programs or practices are positive predictors of adoption, practitioners should share benefits of specific practices and programs and leverage existing practice adoption. Further work to explore relationships between conservation adoption and the role of farmer identity, nuances of land tenure, and the influence of structural factors is needed. Moreover, we suggest that future research should focus on the impact of different messages and avenues of reaching farmers in order to continue to inform conservation practices. Future research should consider both individual and institutional factors that facilitate and constrain adoption.

Key words: agricultural Best Management Practice (BMP)—conservation programs—outreach—program design—social indicators—vote count

Governmental and nongovernmental conservation entities have faced the challenge of getting conservation practices implemented on privately owned agricultural land since the establishment of the federal Soil Conservation Service in the early 1930s (Rasmussen and Baker 1972). Despite efforts to promote soil and water conservation on private agricultural land, and an increasing body of social science literature addressing motivations for and barriers to conservation practice adoption, there are still not enough practices on the ground in the right places in most watersheds to improve both local and end-of-stream conservation outcomes (McLellan et al. 2018).

A little more than a decade ago, Prokopy et al. (2008) reviewed 55 studies published from 1982 to 2007 in the quantitative social science literature to understand determinants of conservation practice adoption in the United States. This work, along with a subsequent meta-analysis of the same data (Baumgart-Getz et al. 2012) and a review of literature from around the globe (Knowler and Bradshaw 2007), all demonstrated that there were very few consistent determinants of adoption. Variables most often positively associated with conservation included education, capital, income, farm size, access to information, positive environmental attitudes, and social networks (Prokopy et al. 2008).

Since these papers were published, the literature exploring the determinants of conservation practice adoption has grown substantially. During the last decade, we know of five attempts to synthesize this burgeoning literature. Tey et al. (2017) focused their efforts on synthesizing 31 studies conducted in what they categorize as developing countries, identifying several socioeconomic and agroenvironmental factors that were relatively consistent predictors of conservation adoption in that context. Liu et al. (2018) took a more global view and look at conservation adoption studies from a diversity of countries; however, their review does not follow a systematic approach and includes review articles, summary fact sheets, and a mix of qualitative and quantitative studies. It is unclear how Liu et al. (2018) categorized and analyzed the studies, which makes it challenging to draw conclusions. Carlisle (2016) performed a narrative review of 43 studies in the soil health literature in the United States (both quantitative and qualitative) and found that farms and farmers are too heterogeneous for decisions and behaviors to be explained by rational actor models. Roussy et al. (2017) performed a nonsystematic review of primarily economics-based literature from around the world and concluded that more

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attention needs to be paid to the role of perceptions in the adoption decision. Finally, Yoder et al. (2018) synthesized a subset of the global literature to examine whether studies connect adoption to biophysical outcomes, whether studies examine adoption within institutional settings, and the relative use of different types of predictive variables. They did not attempt to identify which of these variables are more likely to lead to adoption.

Unlike these five other efforts to synthesize this literature, we focus on all the US-based literature and perform a highly systematic, transparent, and rigorous review. The intention of this paper is to update Prokopy et al. (2008) using both the significance vote-count methodology originally used and a complementary approach that takes signs of estimated regression coefficients and test statistics into account (Bushman and Wang 2009). This paper reviews quantitative studies focused on adoption of agricultural conservation practices in the United States over the period 1982 to 2017.

Materials and Methods

Study Search-and-Screen Process. It was our intent to conduct a comprehensive search of adoption literature. We thus identified all peer-reviewed articles, PhD dissertations, master's theses, and technical reports published during the 35-year timespan of interest for our review. All the studies were English language and focused on the United States. The following inclusion criteria were used to assess candidate studies: (1) date of publication; (2) unit of analysis at the level of farmer/farm operator; (3) dependent variable equals adoption of or willingness to adopt one or more soil and/or water conservation practices; and (4) original empirical research, i.e., not a review article.

In order to systematically identify the greatest number of relevant studies for inclusion, we executed a three-phase search-and-screen process. In the first phase, we used Google Scholar to conduct a reverse citation search for earlier review studies. We collected all of the articles that cited earlier review articles (Knowler and Bradshaw 2007; Prokopy et al. 2008; Baumgart-Getz et al. 2012) and conducted contemporaneous keyword searches in Web of Science and SCOPUS. Results from this phase of the search process yielded 1,632 unique studies.

The second phase of the search-and-screen process involved a review of study titles and abstracts. We identified those that appeared to meet our study inclusion criteria, yielding a total of 279 studies. The third phase of the process involved a full review of each study by two-member combinations of the research team. A total of 172 studies were identified that investigated either farmers' actual adoption or willingness to adopt conservation practices. Forty-nine of these papers used only a qualitative approach and 21 looked only at willingness to adopt. This paper examines only the quantitative papers that examined actual adoption of practices as opposed to willingness to adopt.

Data Extraction Process. Initial data extraction methods were developed based upon a similar project (Floress et al. 2019b): a spreadsheet file was created, followed by data extraction from several papers by all team members to test and refine the process. The project team then followed a two-reviewer, two-level data entry approach that captured study characteristics and individual variable level data for all studies that met our selection criteria for inclusion. Full details of this process are available with Floress et al. (2019a). Following Floress et al. (2019b), detailed information was collected from each study. Results included, as appropriate, variable significance and direction, *p*-value or other statistical significance information, dependent and independent variable means, group (i.e., adopters and nonadopters) means, unstandardized and standardized regression coefficients, *t*-statistics, odds ratios, marginal effects, and model goodness-of-fit statistics, among others.

Categorization of Variables. Initial variable categorization was based on the four categories included in Prokopy et al. (2008) (capacity, attitudes, environmental awareness, and farm characteristics) and their associated subcategories. However, categories and subcategories evolved as coding proceeded.

While numerous subcategories were created and defined, not all variables fit into these subcategories. Variables that were unique or present in very small numbers were thus binned into "other" subcategories within each main category. Some independent variable subcategories did not have obvious hypothesized directionality in terms of the adoption decision and are not included in analyses due to lack of a consistent hypothesized directional effect on adoption. To be included in analysis, a subcategory needed at least 10 observations from at least two studies. An observation is a single row in the data that contains information about a single dependent variable and an associated independent variable, such that a single statistical model of adoption in the database that include multiple independent (explanatory) variable occupies multiple rows, each of which is an individual observation.

In cases where there were multiple dependent variables in a single study, each dependent variable was classified as its own analysis, and data on independent variables were recorded. Conversely, when dependent variables were reported as a composite or index of multiple practices, these were handled as a single outcome. Occasionally, studies included both individual practice analyses and composite analyses; in these cases, the individual practice analyses were reported.

Tables 1 through 7 define the final subcategories and provide the sign of their hypothesized association with dependent variables. Within each table, we first present subcategories expected to have a positive relationship with adoption and then present subcategories expected to have a negative relationship with adoption (where relevant). After dropping subcategories that did not have at least 2 studies, 10 observations, and/or the data necessary to perform each analysis (e.g., an estimated coefficient, test statistic, or information to determine *p*-value) and subcategories that did not have directional interpretations (e.g., weather, geography, or other), 5,417 observations from 92 studies were included in significance vote-counting and 4,116 observations from 81 studies included enough information to calculate confidence intervals required to conduct the Sign Test (Bushman and Wang 2009; described below). Note that there are a total of 93 studies included across all analyses as 1 study included information that could be used in the sign test but not in the significance vote count.

Dependent variables were categorized following a similar approach. Variables were assigned to the following main categories through consensus by a quorum of the team: edge-of-field, conservation program participation (i.e., Environmental Quality Incentives Program [EQIP]), habitat management, livestock management, nutrient management, pest management, soil management, water management, organic, and other. While many practices, e.g., cover crops, can be classified into more than one of these cat-

Table 1
Attitudes category.

Subcategory name	Definition	Hypothesis*
Environmental	Positive environmental attitudes, e.g., New Ecological Paradigm.	Positive
Farmer identity: other	Measure of farmer identity or value orientation: altruistic/steward/innovative/perceive selves as leaders.	Positive
Perception climate	Perception of weather/climate. Climate and weather coded together. Reverse coding for anything that is NOT a belief that climate change is human caused.	Positive
Program/practice	Attitude toward program/practice; conceptualized broadly to include a suite of similar conservation practices. Example, if DV is nutrient management and IV is nitrogen management, then coded under this category/subcategory.	Positive
Risk tolerance	Measures tolerance of risk.	Positive
Farmer identity: self	Measure of farmer identity or value orientation: self-interest/profit.	Negative
Risk aversion	Measures aversion to risk.	Negative
Government regulation	Attitude toward government/government regulation (the higher the number the more positive toward government).	Two-tailed

*Hypothesis denotes hypothesized relationship between dependent variable (DV) and independent variable (IV).

egories, the team collectively decided where practices should be classified based on their primary purpose. It is beyond the scope of this article to look at relationships between subcategories of independent variables and categories of dependent variables.

Attitudes. We categorized independent variables as an "attitude" in table 1 when respondents were asked to evaluate statements related to their opinions, preferences, and perceptions about the following attitude subcategories: environmental (e.g., New Ecological Paradigm; Dunlap et al. 2000), climate perceptions, cost-share, programs/practices, government regulation, and risk. There is a significant body of work in the social science literature on the role that attitudes—one's positive or negative view of an attitude object (Ajzen 1991)—have on behaviors. Though similar attitudes are infrequently measured in the same way (Floress et al. 2017; Vaske 2008), there are general trends in the relationships between certain attitudes and behavior.

Having a positive attitude toward a specific behavior has been shown in many domains to predict behavior, although this relationship is mediated by perceived behavioral control and behavioral intention (Fishbein and Ajzen 2010). Farmers who have a positive attitude toward a specific conservation program or practice also may be more likely to adopt conservation practices. For example, Ulrich-Schad et al. (2017) found that farmers concerned about lack of access for necessary equipment were significantly less likely to use a Nutrient Management Plan or conduct soil tests than those who were not concerned, and Arbuckle and Roesch-McNally (2015) found that perceived benefits of cover crops were related to adopting soil management practices. Others, however, have found specific attitudes and behaviors to not be significantly related. For example, McCann et al. (2015) found nutrient management was not always related to attitudes about the practices. General attitudes are less strongly related to, but still can predict, some behaviors (Gifford and Sussman 2012) such as conservation practice adoption or program participation. For example, Napier et al. (1984) found that farmers concerned about the natural environment were more likely to adopt soil conservation practices than those who were not concerned, and Peterson (2014) found that water quality attitudes were related to several conservation behaviors.

Attitudes based on beliefs about extreme weather and climate change perceptions have been found to be positively related to adopting conservation practices. Mase et al. (2016), for example, found that farmers who believed changing weather patterns were hurting their farms were more likely to adopt in-field conservation practices. Finally, farmers who are risk tolerant may be more willing to adopt conservation (Belknap and Saupe 1988; Kim et al. 2005) than those who are risk averse. Studies of how farmer identities are related to conservation practice adoption have shown that those who have more positive attitudes related to stewardship and "other-interests" may be more likely to adopt practices than those who have higher levels of self-interest (Reimer and Prokopy 2012; Thompson et al. 2015; Floress et al. 2017).

Based on the literature, we hypothesized positive *environmental*, climate perception (*perception climate*), other-interest identity (*farmer identity-other*), *program/practice*, and *risk tolerance* attitudes, respectively, would be positively related to adoption, while attitudes connected to the importance of *cost share*, *risk aversion*, and self-interest identity (*farmer identity-self*) would be negatively related (table 1). Attitudes related to *government regulation* were expected to be related to adoption, but we did not have a hypothesized direction due to insufficient prior evidence.

Behavior. Three subcategories comprise the bulk of the variables in the behavior category (table 2). Current use of closely related, potentially complementary, or sequentially related practices (labeled *program/practice*) is generally thought to be a good predictor of future or more intensive adoption of conservation practices (Lambert et al. 2014). For example, use of variable-rate nitrogen (N) applications has been shown to be positively associated with use of nitrification inhibitors, which reduce the rate at which ammonium (NH_4^+) is converted to nitrates (NO_3) that may leach into groundwater (Weber and McCann 2015). Likewise, cattle producers' adoption of low-stakes pasture improvement practices is associated with their adoption of other, more management-intensive practices such as rotational grazing (Medwid 2016; Lambert et al. 2014). Similarly predicated on this so-called "gateway" effect, the subcategory *other program/practice* entails the adoption of other conservation practices or programs not directly related to the dependent variable of interest. Finally, *crop insurance* was

Table 2
Behavior category.

Subcategory name	Definition	Hypothesis*
Other program/practice	Other conservation programs/practice behaviors than the DV. Used this code only when the other program/practice behavior was about conservation.	Positive
Program/practice	Conservation program/practice behaviors closely related to the DV of interest; conceptualized broadly to include a suite of related conservation practices. Example, if DV is nutrient management and IV is nitrogen management, then coded under this category/subcategory.	Positive
Crop insurance	Used crop insurance.	Negative

*Hypothesis denotes hypothesized relationship between dependent variable (DV) and independent variable (IV).

hypothesized to have a negative effect on the adoption of dependent variables, since conservation practices may be perceived by some operators as a redundant risk-management strategy (i.e., in addition to crop insurance) for buffering themselves against extreme weather events. Similarly, evidence points to a perception among at least some farmers that innovative conservation practices such as cover crops may interfere with previously purchased crop insurance (Arbuckle and Roesch-McNally 2015). However, we recognize that some farmers may view crop insurance as a strategy for managing risk associated with adopting a new conservation technology or practice, such as integrated pest management (Caswell et al. 2001).

Environmental Awareness. Awareness of environmental issues, whether in general or specific to a given behavior, form an important component of several major threads of environmental behavior change research (Fishbein and Ajzen 2010; Rogers 2010; Heberlein 2012). Rogers' (2010) review of diffusion of innovation research places "awareness-knowledge" of behaviors or situations in a critical role in the pathway toward behavioral change, because awareness of a behavior or situation is a first precondition to action. Likewise, Fishbein and Ajzen's (2010) theory of planned behavior (TPB), also referred to as the reasoned action approach, posits that awareness is a precondition to action: if a person is not aware of a given issue or potential solutions to the issue, they are not likely to act to remedy it.

Previous reviews of soil and water conservation practice adoption research (Knowler and Bradshaw 2007; Prokopy et al. 2008; Baumgart-Getz et al. 2012) have all found positive relationships between awareness and adoption. Awareness is a broad and varied concept, however, and we hypothesize a positive relationship between most forms of awareness and adoption of conservation practices, general awareness of agriculture's environmental impacts (*agricultural impact*), knowledge of terms or facts related to environmental quality (*knowledge*), and knowledge of practices and programs (*program/practice*) that may be employed to mitigate such impacts (table 3). Farmers' perceptions of local or regional *environmental quality* (e.g., degree of water quality impairment) is hypothesized to have a negative relationship with adoption.

Information. The influence of information and information sources on decisions and behaviors has long been central to the study of adoption of agricultural practices. As Rogers (2010) noted, information sources can shape initial knowledge of issues or innovations as well as ongoing knowledge development, and actors that are seen as "change agents" can play an active, persuasive role in influencing decisions to adopt or reject a given technology. In the conservation realm, research has shown that farmer engagement with information sources, whether through contacts with public sector sources such as conservation agencies (Gillespie et al. 2007; McBride and Daberkow 2003; Nowak 1987), attendance at field days, workshops or similar events (Nowak 1987; Claytor 2015; Singh et al. 2018), or with private sector agricultural advisors (Eanes et al. 2017), is generally hypothesized to be positively associated with practice adoption.

Prokopy et al. (2008) used the term "networking" to describe information-related variables. The increase in the number of studies using these types of data necessitated a broadening of the category label to "information." We employed three major subcategories of variables in the information category (table 4): *affiliation*, *evaluation*, and *sought/use*. *Affiliation* indicates organizational membership (e.g., farmer group), and may also capture degree of involvement in a given organization. The *evaluation* subcategory generally refers to variables that measure farmers' assessments of the utility of information and information sources; for example,

Table 3
Environmental awareness category.

Subcategory name	Definition	Hypothesis*
Agricultural impact	Awareness of agricultural impacts.	Positive
Knowledge	Knowledge of terms or facts related to environmental quality; a higher score means greater knowledge of environment.	Positive
Program/practice	Knowledge of nonpoint source programs or efforts or practices.	Positive
Environmental quality	Positive farmer's perception of the current quality of the environment.	Negative

*Hypothesis denotes hypothesized relationship between dependent variable and independent variable.

Table 4
Information category.

Subcategory name	Definition	Hypothesis*
Affiliation	Indicates affiliation in an organization; indicative of simply being a member of organization/s; also captures level of involvement in the organization, but that involvement does not necessarily have anything to do with information seeking/use. For example, being a chair vs. being a secretary in an organization, would both be coded as affiliation.	Positive
Evaluation	Indicates information evaluation. For example, whether the source of information was important/useful/easy to use or not; effectiveness, importance, availability of information; includes trustworthiness of information/information sources; reverse code when the information was not enough and a high score would be negative.	Positive
Sought/use	Includes both seeking and/or using information. The code includes level of participation. For example, whether or not farmer ever participated in education programs. Also code for source of information.	Positive

*Hypothesis denotes hypothesized relationship between dependent variable and independent variable.

Table 5
Farm characteristics category.

Subcategory name	Definition	Hypothesis*
Acres	Farm size, includes total acres, log acres, and number of acres farmed or operated. Does not include acres squared.	Positive
Diversity	More than one crop in rotation (beyond just corn [*Zea mays* L.]/soybean [*Glycine max* L.] or other crops typically grown together), more than one crop, more than one type of livestock, or livestock and crop.	Positive
Institutional	Presence of institutional, legal impacts on land or farm's presence within a watershed area with activities.	Positive
Livestock	Livestock or dairy operations.	Positive
Livestock number	Number of livestock.	Positive
Row crop	Measures whether a farm grows row crops; includes primarily row crop, percentage row crop, binary row crop; does not include percentage of income from row crops; does not include acres, which is considered a proxy for farm size.	Positive
Tenure	Percentage or proportion of operated land that is owned; if field level variable, field is owned; entire farm is owned. If variable is measure of rented land, it is reverse coded. Also a measure of lease security (e.g., written lease).	Positive
Vulnerable	Measures of vulnerable land, e.g., higher levels slope, highly erodible land, pest presence, and leaching.	Positive
Waterbody	Farm located near a lake, stream, or in a river bottom, wetland.	Positive
Soil quality	Measure of good soil quality; clay and sand assumed to be poor soil quality and reverse coded.	Negative

*Hypothesis denotes hypothesized relationship between dependent variable and independent variable.

perceived effectiveness or trustworthiness of information. *Sought/use* was the largest subcategory, comprising variables indicating that farmers actively sought out and/or used conservation-related information. Information seeking actions included participation in educational programs such as field days, workshops, and other learning opportunities.

Farm Characteristics. Farm characteristics are often included in adoption studies, emphasizing the level of importance these characteristics may have in decisions to adopt conservation or the ease with which these variables are measured. Types of variables coded as farm characteristics (table 5) include *vulnerability* (usually higher land slope or highly erodible land), adjacency to a *waterbody*, type of operation (e.g., crop or livestock), land *tenure*, and the number of *acres* farmed.

While the majority of studies include one or more farm characteristic variables, these are frequently not the variables of interest, but rather are included as covariates or control variables. Following the literature, which generally hypothesizes positive relationships between farm characteristics and conservation adoption, we posit a positive hypothesis for all subcategories except for *soil quality* (table 5). Prior research indicates, for example, that the size of the farm (*acres*) increases adoption of many types of conservation practices including conservation tillage (Belknap and Saupe 1988), water conservation (Dorfman 1996; Gottlieb et al. 2015), cover crops (Dunn et al. 2016), nutrient management (Caswell et al. 2001), and rotational grazing (Gillespie et al. 2007). Land *tenure* is considered an important construct (Soule et al. 2000); when farm operators own the land they manage, studies have observed an increase in the level of adoption of a number of practices including nutrient management (Bosch et al. 1995; Khanna 2001), pest management (Caswell et al. 2001), and soil management practices (Lichtenberg 2004).

Table 6
Operator characteristics category.

Subcategory name	Definition	Hypothesis*
Farming occupation	Full-time farming occupation, intention to be full-time farmer.	Positive
Formal education	Formal education, with high school or less reverse-coded.	Positive
Succession	Plans to pass farm on.	Positive
Training	Training and technical skill with technology.	Positive
Age	Farmer age.	Negative
Farming experience	Years farming.	Negative
Operator sex	Male.	Negative
Retired	Retired operators.	Negative

*Hypothesis denotes hypothesized relationship between dependent variable and independent variable.

Operator Characteristics. Like farm characteristics, variables classified as operator characteristics (table 6) are often included in conservation practice adoption research. This may be because operator characteristics are easily measured on surveys and are important for understanding who is choosing to adopt a practice. We hypothesize that having a *farming occupation*, higher level of *formal education*, having a *succession* plan, and agricultural *training* will all have a positive association with adoption. For example, the level of *formal education* an operator had attained (e.g., high school degree or college degree) had a positive relationship with soil management (Barbercheck et al. 2014), nutrient management (Gedikoglu et al. 2011), and maintaining setbacks (McCann et al. 2015). Those who have attained higher levels of *formal education* may be more likely to adopt conservation due to an increased ability to search out new information on conservation and farm management and apply it to their operation.

We hypothesize that *age*, *farming experience*, *operator sex*, and being *retired* will be negatively associated with adoption. *Age*, for example, is found to have a negative effect on adoption (i.e., the older a farmer is, the less likely they are to adopt a practice) of grazing practices (Barbercheck et al. 2014), soil management (Lichtenberg 2004), manure testing (McCann et al. 2015), and influences levels of investment in conservation (Featherstone and Goodwin 1993).

Economic Factors. We identified numerous different economic factors (table 7) that were included as independent variables in at least one conservation practice adoption study from the literature. We hypothesize that measures of the health or size of the *agricultural economy* (adoption of conservation tillage and soil nutrient tests in Kara et al. 2008), *capital* (farm-level assets) (Nganje et al. 2007), *crop value* (Kraft et al. 1996), *livestock value* (Napier et al. 1984), and *land value* (Loftus and Kraft 2003) are all positively correlated with adoption because, all else equal, better market or personal financial conditions may reduce or eliminate economic constraints on adopting conservation or other management practices. Similarly, *income*, *income: farm* (Napier et al. 2000; Gillespie et al. 2007), and *sales* (Thomas et al. 1990; Wu and Babcock 1998) variables, or engaging in *marketing* practices (Khanna 2001; McNamara et al. 1991) to maximize revenues or profits are expected to be positively related to practice adoption. Having more *labor* available (Cooper and Keim 1996) to install practices and learn about or undertake new management activities are expected to be positively related to adoption, as is expecting a *yield* increase (Rahelizatovo 2002; Wu et al. 2004).

Table 7
Economic factors category.

Subcategory name	Definition	Hypothesis*
Agricultural economy	Measures of state GDP, county equivalent, commodity prices, etc. (Includes measures of practice profitability at the county level.)	Positive
Capital	Monetary measure of assets or investment into farm; includes access to credit, includes debt-asset ratio (reverse code).	Positive
Crop value	Value of crops raised/produced on a farm (US$ amount).	Positive
Income	Measures of income, including crop value, etc.	Positive
Income: farm	Income from farm.	Positive
Labor	Measures of increased labor available to the farm. Family on-farm labor included.	Positive
Land value	Measures of land value.	Positive
Livestock value	Value of animals raised/produced on a farm (US$ amount).	Positive
Local economy	Measures of local economy includes non-ag; measures include employment and dollar amount.	Positive
Marketing	Marketing arrangements (e.g., forward contracts).	Positive
Sales	Farm revenue.	Positive
Willingness to accept (WTA)	Measure of WTA; may be binary.	Positive
Yield	Positive yield impact expected.	Positive
Input cost	Input prices, cost of inputs; includes labor, machinery, etc.	Negative

*Hypothesis denotes hypothesized relationship between dependent variable and independent variable.

Table 8
Selected study characteristic frequencies of included studies.*

Study characteristic	Number	Percentage
Theoretical grounding (*n* = 93)		
Complete theoretical framework	45	48.39
Theory used in literature review	24	25.81
No theory employed	22	23.66
Theory incorporated into discussion	2	2.15
Specific theory (*n* = 71)		
Microeconomic theory	21	29.58
Multiple	20	28.17
Diffusion of innovations	14	19.72
Other	13	18.31
Theory of planned behavior	3	4.23
Primary data collection method (*n* = 93)†		
Mail survey	49	52.69
Secondary quantitative data	19	20.43
Structured interview (quantitative)	11	11.83
Phone survey	6	6.45
Other data collection method	3	3.23
Drop-off pick-up	2	2.15
Not described/other	2	2.16
Semistructured interview (qualitative)	1	1.08
Primary sampling method (*n* = 97)†		
Simple random	25	26.88
Not described	23	24.73
Stratified random	17	18.28
Census	15	16.13
Nonrandom	6	6.45
Systematic random	4	4.30
Other	3	3.23

*92 studies were included in significance counting; 81 in sign tests. One study from the sign test analysis was not included in significance counting.

†Multiple methods were used in some studies. These data represent only the primary method.

Analysis Methods. A significance vote count of the number of times an independent variable subcategory was found to be not statistically significant, statistically significant and negative, or statistically significant and positive at the $p \leq 0.05$ level was conducted and is analogous to the approach and presentation of findings reported in Prokopy et al. (2008).

In an effort to use as much information as possible from the database of research articles compiled and further understand positive and negative relationships between subcategories and conservation practice adoption or program participation, we used a second analysis to complement the vote count results. Specifically, we followed procedures suggested by Bushman and Wang (2009) to test hypotheses about the simple direction (positive or negative sign of an estimated effect size coefficient) in addition to significance for each independent variable subcategory. We developed directional hypotheses (detailed in tables and text above for each independent variable subcategory grouping) for 46 category/subcategory combinations of independent variables for which a hypothesis was conceptually and methodologically defensible.

We calculated Wilson's confidence intervals (CI) for binomial proportions (Brown et al. 2001) to test whether or not the 95% CI bounds include the value 0.50, i.e., whether the interval was positive (negative) more than 50% of the time as would be expected by chance alone with each study representing a probabilistic toss of a coin. Usually, CI estimate population parameters. However, in the case of metaanalyses, the population is all of the studies that have previously investigated the question of interest, and the sample is the papers included in the meta-analysis. Thus, the CI we calculate represent the population of research articles, not the population of individuals adopting conservation practices.

Tables 9 through 16 present results broken down by category. In interpreting the data, it is helpful to look at both the results of the vote count and the sign test. All of the data prepared for this study are available in the study database (Floress et al. 2019a).

Results and Discussion

Study Characteristics. This section summarizes key study characteristics extracted from each of the 93 quantitative studies of adoption of practices or programs included in at least one of the analyses.

Among the dependent-variable/independent-variable pairs included in our analyses, the largest group of dependent variables were classified as nutrient management practices (38%), followed by soil management practices (24%). In descending order, other dependent variables included livestock management (11%), other (10%), pest management (7%), edge-of-field (6%), water management (4%), organic (1%), conservation program participation (1%), and habitat management (<1%).

The spatial scale of the studies varies; scales include single watershed or county, multiple watersheds or counties, single state, multiple states either adjacent or not, and nationwide. Similarly, the geographic range of the studies varies extensively with data from across the contiguous 48 states. These study locations are included in the database generated for this study (Floress et al. 2019a) but examining differences across geographies is beyond the scope of this paper.

Table 8 includes percentage distributions for selected categorical measures collected in study-level characteristics. We used four categories to record the varied ways that study authors incorporated theory into their studies. Forty-eight percent of studies employed what we termed a "complete theoretical framework," meaning that the study incorporated theory into the literature review, guided variable selection and hypothesis generation, and engaged with theory in the discussion/conclusion section. Twenty-four percent of studies did not use theory, 26% engaged with theory only in the literature review, and 2% reference theory only in the discussion/conclusion section.

Table 9
Attitudes—Sign test and significance vote count.*

Subcategory (hypothesis)	Significance vote count: # of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	Coefficients–Sign test: # of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Environmental (+)	105 (11)	1	94	10	9.52 (10/105)	89 (8)	0.50	0.70	0.61†
Farmer identity: other (+)	103 (12)	2	76	25	24.3 (25/103)	98 (11)	0.58	0.76	0.67†
Perception climate (+)	20 (2)	0	19	1	5.00 (1/20)	21 (3)	0.41	0.79	0.62
Program/ practice (+)	378 (28)	43	237	98	25.9 (98/378)	262 (27)	0.57	0.69	0.63†
Risk tolerance (+)	20 (6)	1	17	2	10.0 (2/20)	24 (6)	0.35	0.72	0.54
Farmer identity: self (–)	26 (6)	4	21	1	15.4 (4/26)	27 (5)	0.25	0.59	0.41
Risk aversion (–)	82 (7)	9	68	5	11.0 (9/82)	66 (7)	0.29	0.51	0.39
Government regulation (+/–) ‡	32 (7)	2	26	4	n/a		—	—	—

*Definitions for the attitudes category are included in table 1.
†Variables are positive/negative more often than expected by chance.
‡Two-tailed hypotheses are not included in the sign test.

For the 71 studies that referenced theory in some way, we recorded the specific theory used. Twenty-eight percent used multiple theoretical perspectives, 30% employed microeconomic theory, 20% used some variant of diffusion of innovations, and 4% used theory of planned behavior. Many of the studies that employed multiple theoretical perspectives used a combination of diffusion of innovations and microeconomic theory. Eighteen percent employed one of a range of theoretical perspectives that we categorized as "other."

Information was recorded about research design including data collection method and sampling approach. A majority (53%) of the quantitative studies used mail surveys as their primary data collection method, 20 used secondary quantitative data, 12% used in-person structured interviews, and 6% employed phone surveys.

The most common sampling method was simple random (27%). Census (16%) and stratified random (18%) were also relatively common. The remaining studies used some systematic random sampling (4%), other sampling approach (3%), nonrandom approaches (6%), or did not report their sampling method (25%).

Quantitative Results. A total of 5,417 independent variable observation rows from 92 studies were included in significance vote counts, and 4,116 rows from 81 studies included coefficient or test statistic data required to conduct a sign test. Where significance information was available, a majority of variables were found to be not statistically significant as Prokopy et al. (2008) found. Overall, 76% of variables were not statistically significant, 7% were significant and negatively correlated with the dependent variables, and 17% were positively correlated.

Tables 9 through 15 present the results for each of the categories of variables. The first four results columns are for the significance vote count and the latter four are for the sign test.

Attitudes. There are eight attitude subcategories with enough information to analyze (table 9). Attitudes toward a program or practice (*program/practice*) emerged as the strongest predictor of adoption with almost 26% of the variables having a significant and positive relationship with adoption and 11% of the variables having a negative relationship. Similarly, about 24% of the variables categorized as *farmer identity: other* were positive. For both of these subcategories, the trend toward a positive relationship is confirmed with the sign test results where we see that positive coefficients are found in the data set more often than we would expect by chance (the entire 95% CI lies above 0.5). While only about 10% of the *environmental* attitudes were significant and positive, the sign test indicates that they are right on the threshold of being positively related to adoption based on the sign test (CI lower bound = 0.5). The majority of attitude variables, however, do not appear to have a statistically significant relationship with adoption.

Behavior. Both already engaging in a closely related practice (or having engaged in the past with the practice or a similar practice—*program/practice*) and engaging in other conservation practices (*other program/practice*) are positively related to adoption as shown by both the significance vote count and the sign test (table 10). *Crop insurance* does not appear frequently in the studies; however, when it does appear, it is positive more often than negative, which is the opposite of what we expected to find. This suggests that crop insurance is at least sometimes correlated with conservation practice adoption and it is not necessarily a deterrent.

Environmental Awareness. While awareness of *agricultural impact* on the environment was hypothesized to have a positive relationship with adoption, this does not appear to be a strong relationship with 28 positively significant instances, 18 negatively significant instances, and 203 not-significant instances in the data (table 11). Environmental *knowledge* is positive 14% of the time, indicating that it might be an important variable, although the variable is not positive any more often than we would expect by chance based on the sign test. Having knowledge specific to the programs or practices (*program/practice*) being studied is positive and significant 22% of the time and positive more often than we would expect by chance.

Table 10
Behavior—Sign test and significance vote count.*

	Significance vote count					Coefficients–Sign test			
Subcategory (hypothesis)	# of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	# of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Other program/ practice (+)	258 (30)	12	189	57	22.1 (57/258)	243 (30)	0.62	0.74	0.68†
Program/ practice (+)	54 (10)	0	40	14	25.9 (14/54)	45 (8)	0.59	0.84	0.73†
Crop insurance (–)	27 (6)	1	19	7	3.70 (1/27)	17 (5)	0.22	0.64	0.41

*Definitions for the behavior category are included in table 2.
†Variables are positive/negative more often than expected by chance.

Table 11
Environmental awareness—Sign test and significance vote count.*

	Significance vote count					Coefficients–Sign test			
Subcategory (hypothesis)	# of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	# of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Agricultural impact (+)	249 (5)	18	203	28	11.2 (28/249)	73 (5)	0.41	0.63	0.52
Knowledge (+)	80 (7)	1	68	11	13.7 (11/80)	80 (6)	0.45	0.67	0.56
Program/ practice (+)	58 (8)	2	43	13	22.4 (13/58)	56 (7)	0.66	0.87	0.79†
Environmental quality (–)	47 (8)	5	37	5	10.6 (5/47)	45 (8)	0.29	0.57	0.42

*Definitions for the environmental awareness category are included in table 3.
†Variables are positive/negative more often than expected by chance.

Table 12
Information—Sign test and significance vote count.*

	Significance vote count					Coefficients–Sign test			
Subcategory (hypothesis)	# of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	# of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Affiliation (+)	109 (5)	10	85	14	12.8 (14/109)	111 (7)	0.40	0.58	0.49
Evaluation (+)	86 (9)	7	70	9	10.5 (9/86)	45 (8)	0.39	0.67	0.53
Sought/use (+)	360 (32)	10	270	80	22.2 (80/360)	265 (28)	0.63	0.74	0.69†

*Definitions for the information category are included in table 4.
†Variables are positive/negative more often than expected by chance.

Information. Seeking or using information (*sought/use*) is positively related to adoption in both the significance vote count and the sign test (table 12). Being affiliated with or involved in an organization (*affiliation*) has mixed results in the vote count with the variable being negative almost as often as it is positive. This is perhaps an indication of the fact that not all organizations are prone to promoting conservation—a nuance that was not captured by this variable. *Evaluation* of information also has similarly mixed results.

Farm Characteristics. Ten subcategories of farm characteristics had enough information to be included in our analysis. Looking at the significance vote count and the sign test, farm size (*acres*), *diversity*, *livestock number*, *row crop*, environmentally *vulnerable*, and *waterbody* are all found to be positively related to adoption more often than we would expect by chance (table 13). The significance vote count also shows that *institutional* is positive and significant more often than negative and significant, as expected, while *livestock* is almost evenly split when it is significant. *Tenure*, as defined by owning versus renting land or having a more secure lease, was hypothesized to have a positive relationship with adoption. However, in the significance vote count,

Table 13
Farm characteristics—Sign test and significance vote count.*

Subcategory (hypothesis)	Significance vote count: # of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	Coefficients–Sign test: # of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Acres (+)	253 (54)	10	180	63	24.9 (63/253)	194 (49)	0.57	0.70	0.64†
Diversity (+)	103 (11)	6	70	27	26.2 (27/103)	98 (11)	0.64	0.81	0.73†
Institutional (+)	45 (13)	7	22	16	35.6 (16/45)	37 (10)	0.49	0.78	0.65
Livestock (+)	173 (18)	30	118	25	14.5 (25/173)	136 (16)	0.38	0.55	0.46
Livestock number (+)	56 (8)	3	48	5	8.93 (5/56)	42 (7)	0.56	0.83	0.71†
Row crop (+)	67 (14)	6	36	25	37.3 (25/67)	46 (13)	0.57	0.83	0.72†
Tenure (+)	284 (38)	20	238	26	9.15 (26/284)	201 (36)	0.43	0.57	0.50
Vulnerable (+)	211 (29)	14	141	56	26.5 (56/211)	138 (28)	0.75	0.87	0.82†
Waterbody (+)	98 (13)	7	76	15	15.3 (15/98)	79 (12)	0.56	0.76	0.67†
Soil quality (–)	54 (13)	15	23	16	27.8 (15/54)	44 (12)	0.34	0.62	0.48

*Definitions for the farm characteristics category are included in table 5.

†Variables are positive/negative more often than expected by chance.

this is positive only slightly more often than it is negative, and not significant in the vast majority of observations.

Operator Characteristics. Findings for both the significance vote count and the sign test indicate that *farming occupation* and *formal education* are positive and significantly related to adoption more often than we would expect by chance (table 14). However, farming occupation does not appear in many studies. *Training* is found in the significance vote count to be positive and significant and never found to be negative and significant. While training never had a negative and significant impact on adoption, it does not appear in enough studies to be a very conclusive finding. Years of *farming experience* is expected to be highly correlated with *age* and, like *age*, is negative and significant more often than it is positive in the significance vote count but is not negative more often than we would expect by chance according to the sign test.

Economic Factors. *Income*, *marketing*, *willingness to accept*, and *yield* were all found to be positively correlated with adoption as revealed by both the significance vote count and the sign test (table 15). However, in the significance vote count, the results for *marketing* show only two studies having a positive and significant finding. Income from farm (*income farm*) has a more positive than negative relationship in the significance vote count results. *Labor*, which was hypothesized to have a positive relationship with adoption, actually has more negative than positive significant results. The *agricultural economy* and *sales* are both only positive when they are significant; however, neither are included in enough studies to draw strong conclusions.

Table 14
Operator characteristics—Sign test and significance vote count.*

Subcategory (hypothesis)	Significance vote count: # of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	Coefficients–Sign test: # of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Farming occupation (+)	13 (4)	1	7	5	38.5 (5/13)	14 (4)	0.52	0.92	0.79†
Formal education (+)	331 (57)	14	254	63	19.0 (63/331)	253 (52)	0.58	0.69	0.64†
Succession (+)	72 (11)	4	63	5	6.94 (5/72)	55 (9)	0.45	0.70	0.58
Training (+)	31 (4)	0	22	9	29.0 (9/31)	20 (3)	0.43	0.82	0.65
Age (–)	251 (46)	25	217	9	9.96 (25/251)	192 (43)	0.46	0.60	0.53
Farming experience (–)	178 (30)	17	148	13	9.55 (17/178)	126 (29)	0.34	0.51	0.42
Operator sex (–)	61 (9)	3	53	5	4.92 (3/61)	52 (8)	0.25	0.50	0.37
Retired (–)	24 (4)	1	23	0	4.17 (1/24)	21 (4)	0.24	0.63	0.43

*Definitions for the operator characteristics category are included in table 6.

†Variables are positive/negative more often than expected by chance.

Table 15
Economic factors—Sign test and significance vote count.*

Subcategory (hypothesis)	Significance vote count: # of rows (# of studies)	Neg.	Not sig.	Pos.	% of rows consistent with hypothesis	Coefficients–Sign test: # of rows (# of studies)	Lower 95% confidence interval bound	Upper 95% confidence interval bound	Proportion consistent with hypothesis
Agricultural economy (+)	42 (2)	0	34	8	19.0 (8/42)	44 (3)	0.47	0.74	0.61
Capital (+)	157 (20)	3	135	19	12.1 (19/157)	113 (18)	0.45	0.63	0.54
Crop value (+)	15 (4)	0	12	3	20.0 (3/15)	—	—	—	—
Income (+)	130 (21)	5	109	16	12.3 (16/130)	107 (17)	0.60	0.77	0.69†
Income farm (+)	245 (22)	17	189	39	15.9 (39/245)	164 (22)	0.45	0.63	0.53
Labor (+)	172 (19)	27	132	13	7.56 (13/172)	133 (19)	0.44	0.61	0.53
Land value (+)	29 (3)	6	17	6	20.7 (6/29)	29 (3)	0.12	0.42	0.24
Livestock value (+)	28 (7)	1	23	4	14.3 (4/28)	17 (6)	0.47	0.87	0.71
Marketing (+)	24 (3)	1	21	2	8.33 (2/24)	24 (3)	0.55	0.88	0.75†
Sales (+)	17 (6)	0	10	7	41.2 (7/17)	17 (6)	0.36	0.78	0.59
Willingness to accept (+)	24 (4)	0	10	14	58.3 (14/24)	21 (3)	0.65	0.95	0.86†
Yield (+)	29 (5)	0	21	8	27.6 (8/29)	29 (5)	0.74	0.96	0.90†
Input cost (–)	106 (4)	16	76	14	15.1 (16/106)	103 (4)	0.39	0.58	0.49

*Definitions for the economic factors category are included in table 7.

†Variables are positive/negative more often than expected by chance.

Summary and Conclusions

As in Prokopy et al. (2008), some variables emerge in the analyses presented here that have a statistically positive relationship more often than a negative relationship and coefficients that are positive more often than we would expect by chance. Consistent with Prokopy et al. (2008), these variables include environmental attitudes, farm size, increased levels of formal education, having vulnerable land (measured only as slope in 2008), and awareness of a program/practice. Actively seeking/using information is similar to the networking measure used in Prokopy et al. (2008) and is again found to be an important determinant of adoption. Other variables that emerge as having a statistically positive relationship more often than we would expect by chance include farmers self-identifying as not being primarily motivated by finances, having a positive attitude towards the particular program or practice, having already adopted other conservation practices, engaging in marketing that increases price received for production, and adoption having a positive expected effect on yield. Further work needs to be done to examine what types of positive attitudes towards programs or practices are most influential. Age is the only variable that emerges as a negative predictor of adoption, as it did in Prokopy et al. (2008). None of the findings from this analysis are contradictory to the Prokopy et al. (2008) findings; the increased number of studies available for this updated vote count simply allowed for more-refined measures of independent variables.

These findings are consistent with several of the theories and frameworks often employed in the literature to explain or predict farmer behavior. Being aware of a program or practice and forming a positive attitude toward the program or practice are critical steps in the diffusion of innovations framework (Rogers 2010). Having a positive attitude toward a program or practice is also important in the theory of planned behavior (also called the reasoned action approach) (Fishbein and Ajzen 2010). Forming these positive attitudes is often related to having adopted similar behaviors in the past, which also increases perceived behavioral control, an important element in the reasoned action approach. Income is likely correlated with using marketing arrangements that maximize profits and having more capacity—as measured by farm size—which are important in microeconomic theory, and also consistent with the positive finding about human capital (formal education). Having an identity that is not primarily focused on financial motivations is consistent with the value-belief-norm theory (Stern 2000). Indeed, more and more research has examined relationships between farmers' conservation/stewardship ethic and conservation behavior. This "ethic" or stewardship identity relates to a person's sense of responsibility toward land management that improves on- and off-farm resources and/or the well-being of people (Eaton et al. 2019). It is possible that underlying farmer values feed into farmer identity, and these identities can influence conservation behavior (Floress et al. 2017). Not all farmers primarily identify as stewards or innovators, thus developing a better understanding of elements within financial motivation is warranted; qualitative data could help inform the development of more nuanced identity measures in survey research.

Similar to the work conducted in Prokopy et al. (2008) on a smaller set of studies, some demographic variables frequently included in adoption studies are important predictors of adoption (e.g., farm size and education). While these can help conservation professionals target messaging, the research community must continue to identify new variables that are better explanatory measures of adoption decision. Moreover, the research community may want to pursue data collection and statistical methods capable of accounting for previously unobserved (or rarely measured) variables that may be correlated with other covariates.

Some variables hypothesized to be important that were only employed in a small number of studies include how farmers evaluate information, farmers' affiliative networks, the state of the agricultural economy, farm sales, the use of crop insurance, presence of institutional factors such as regulations, and the role of training. The data presented here are suggestive that these variables are all positively associated with the adoption decision; however, these variables need to be included in more studies in order to draw firmer conclusions. Crop insurance, while not included in many studies, did not conform to our hypothesis that it would have a negative impact on adoption, and this needs to be further explored. The results for land tenure presented here were surprising. The lack of clear influence is perhaps due to the simplicity with which this variable is typically measured—often just by ratio of land rented to total land farmed (Gillespie et al. 2007; Peterson 2014) or a binary measure of whether farmers rented land or not (Arbuckle and Roesch-McNally 2015). This suggests that a more precise measure of land tenure—e.g., one that captures whether a practice is adopted on owned or rented land, or a farmers' perceived stability and/or anticipated longevity of a lease arrangement, rather than simply whether the land is rented or not—may be needed to more effectively understand how ownership or tenancy may influence levels of adoption.

There are a number of additional variables that may be worthy of more consideration that do not appear in the tables presented here due either to very low frequency of occurrence or because they are only included in willingness-to-adopt studies, which are not reviewed here. These include awareness of the impact one's own farm has on the environment (Napier and Tucker 2001), trust in government (Lubell et al. 2013), a farmer's sense of place (Mullendore et al. 2015), overall farmer satisfaction and satisfaction with stress level (Winsten et al. 2011), farmers' mental health (Burnett 2014), the role of collective decision making (Stallman and James 2017), farm distance to urban centers (Zhang et al. 2016), and distance to critically affected bodies of water like Lake Erie (Wilson et al. 2014). Other variables suggested by common social science theories do not seem to be frequently or effectively operationalized in the farmer conservation practice adoption literature; prominent among these missing variables is the role of social norms (Schwartz 1977; Stern 2000; Fishbein and Ajzen 2010).

Another important observation drawn from our review is that quantitative research has not focused enough attention on barriers to adoption, especially cultural (e.g., community norms) and structural (e.g., policy-market interface) barriers to behavioral change (Carlisle 2016; Roesch-McNally et al. 2018). As the tables above show, most independent variables included in adoption studies are hypothesized to be positive predictors. There are important exceptions such as (lack of) elements associated with perceived behavioral control (e.g., knowledge and economic capacity) and (lack of) tenure. Overall, however, we conclude that quantitative research should increase efforts to measure barriers/negative predictors of adoption at both the individual/farm and structural levels. To that effect, qualitative studies and their synthesis can provide a fruitful starting point (Ranjan et al. 2019).

Our review also highlights a critical shortcoming in the literature: a majority of variables used in adoption studies have a social-psychological emphasis and largely exclude structural factors that may influence adoption. These structural factors merit far greater attention as it is difficult or perhaps impossible to effect social change by focusing solely on individual behavior change because individual behavior is located within a larger system (Shove 2010). As Buttel (2006) proposed, social structural factors such as subsidies and publicly funded research priorities have driven major increases in specialization, monoculture, and spatial homogeneity of crops, dependence on purchased inputs (especially synthetic fertilizers and pesticides), and geographic concentration of livestock and livestock waste. These in turn are primary drivers of unsustainability indicators such as water quality impairment, soil degradation, and pesticide resistance that necessitate soil and water conservation practices in the first place. In addition to ecological impacts, these same agricultural policies have been implicated in the intensification of what Cochrane (1993) termed "the agricultural treadmill"—a process that leads to conditions of chronic oversupply and low or negative profits that may greatly constrain farmer capacity to invest in soil and water conservation. Inadequate attention to such structural factors has likely hampered the ability of quantitative adoption research to account for substantial drivers of farmers' adoption decision making.

Approximately one-third of all studies included in this review did not incorporate theory into their work. We suggest that a stronger emphasis on theory will likely help identify additional determinants of conservation adoption or inform how to effectively operationalize the variable; see Stern (2018) for a review of theories that help explain human behavior. Furthermore, all of the studies we reviewed made the normative assumption that adoption of conservation practices was a good thing for a farmer to do. Future research should query this assumption more directly. Additionally, as noted by Reimer et al. (2014), many quantitative studies suffer from a myopic view on how to measure adoption (binary, yes/no) with only a few studies measuring intensity of adoption (measured as the number of acres on which a given practice is implemented, frequency of use, or by increased number of different practices), and even fewer studies look at adoption of two mutually beneficial practices such as soil testing together with use of variable rate technology (Khanna 2001; Carlisle 2016). There is also little to no focus on adoption over time, a phenomenon that is referred to as maintenance and persistence in the literature (Dayer et al. 2018; Reimer et al. 2014).

One of the biggest challenges when reviewing the empirical literature on adoption of BMPs is the extremely large variation in how the statistical models estimated are specified. Certainly, different researchers will take different approaches and have different data available to them to include as explanatory variables, especially when you consider that economists, planners, sociologists, and other environmental social scientists all start from different disciplinary origins, have different methodological training, and there may be different formal or informal standards for how estimation results are reported (i.e., including model fit statistics, sample sizes, and test statistics for overall significance) between and even within disciplines. The desire to present a novel model in many cases may be a necessity for peer-reviewed publication, but if a baseline or standard model of adoption is not presented alongside alternative specifications or different statistical models, then systematic review and meta-analysis cannot directly compare the findings from different studies of the same practices in different locations, institutional settings, or at different points in time. Further, without presenting at least two different models or specifications of the same statistical model side-by-side, it is impossible to evaluate whether the differences in findings of both significance and the magnitude of effect sizes is due to specification choices. The issue of adoption model specification is a topic ripe for greater attention in the adoption literature that could be explored in future research. It is likely that some independent variables have inconsistent findings because models in the literature are inconsistently specified, or, quite possibly, incorrectly specified. While we can never know if an estimated model specification is truly "correct"—reflects the true underlying data generating process—the selection of a best-fitting model based on one or more accepted statistical criteria is standard scientific practice (Browne and Cudeck 1993). Inconsistent findings might be explained by different specifications or different levels of measurement of independent variables (Baumgart-Getz et al. 2012). More research on the role of inter-study variation as a determinant of different findings across studies is planned using the study database (Floress et al. 2019a) but is outside the scope of this review. Without a coordinated effort to adopt standards of reporting adoption model results it will be impossible to definitively know whether the effects of independent variables truly are different in different contexts or if the inconsistent effects found in different studies are due to alternative specifications of variables and/or behavioral models of adoption. While researchers cannot in practice recover the true model, we can endeavor to estimate and report the best specified model based on the relative goodness-of-fit under alternative specifications.

In conclusion, there are still many aspects of farm/farmer conservation adoption decision making that we do not understand. In addition to issues discussed above, future research should examine whether decision making is differently motivated based on practice type and could also explore within the independent variable categories presented here to see if there are further nuances that can be uncovered. However, a key takeaway for conservation professionals is the importance of social networks—farmers who seek and use soil and water conservation information and who interact in conservation-related networks (e.g., contacts with natural resource professionals or participation in conservation-related programs) are more likely to adopt practices. A related key takeaway is that both awareness of and positive attitudes toward the actual program or practice to be adopted are found to be positive predictors of adoption. This is consistent with Fishbein and Ajzen's (2010) reasoned action approach, which argues that object-specific attitudes are more important than general attitudes. Thus, helping farmers form specific attitudes about specific programs and practices is critical to adoption. This suggests that conservation professionals (and agricultural input suppliers) should focus their efforts on providing specific information about both the positive elements and potential risks of specific practices or programs. Relatedly, this necessitates further innovation in conservation practice development to develop practices toward which farmers can more readily form a positive attitude.

However, forming a positive attitude toward a particular practice is often not sufficient to lead to adoption in isolation of other factors. As our results indicate, one of these factors can be the farmer's identity. This relatively new area of inquiry is highlighting the importance of farmer identities in leading to adoption. A potential research question therefore relates to messaging: is conservation currently marketed using words and concepts that resonate better with stewardship-motivated farmers than financially motivated farmers? It is imperative for both the conservation and research communities to evaluate how well different messages work with different populations of farmers, and which practices might be related to different farmer identities. We look forward to observing the literature on determinants of conservation adoption evolve over the next 10 years to focus on the impact of different messages and avenues of reaching farmers so it can continue to inform conservation practice.

That said, in closing we want to emphasize that adoption research should employ more comprehensive theoretical lenses and examine both individual-level and structural factors. Farmers and other land managers make decisions in complex contexts within which factors such as markets, policies and programs, and other social institutions can facilitate or constrain behavioral change (NRC 2010). Individual-level demographic and farm characteristics, attitudes, awareness, identity, and so forth undoubtedly play a role in conservation decision making, yet our analyses show that in general they are not powerful and consistent predictors of soil and water conservation practice adoption. Research that takes individual-level and structural factors into account—both facilitators and constraints—will likely be more effective in providing a better understanding of adoption processes.

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Disclaimer

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