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Cover crops and specialty crop agriculture: Exploring cover crop use among vegetable and fruit growers in Michigan and Ohio

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Abstract: Cover crops—crops grown primarily to protect and improve soil—are widely considered to be an important component of sustainable agricultural systems because their use can provide multiple ecosystem services without compromising yields over time. Specialty crops—fruits, vegetables, and horticultural crops—are increasingly important to US agriculture and food security and uniquely vulnerable to climate-related problems that cover crops can help to address. Yet far less research has been conducted on cover crop use by farmers who grow mainly specialty crops, compared to the much larger body of research on farmers who principally grow row crops like corn (*Zea mays*) and soybeans (*Glycine max*). In this study, we draw on survey data from a stratified, random sample of 881 specialty crop growers in Michigan and Ohio to accomplish two main goals. First, we seek to characterize cover crop use among this important group of farmers, focusing on types of cover crop used and use of multiple types. Second, we examine the relationship between cover crop use on vegetable and fruit farms and key social and economic factors, with particular attention to farmers' environmental values, adherence to organic principles, and sources of information. According to survey results, cover cropping is more likely when farmers (1) manage certified organic ($p < 0.01$) or organic-in-practice ($p < 0.05$) farms; (2) report being influenced by private crop consultants ($p < 0.01$); (3) attach high importance to agri-environmental goals ($p < 0.01$); and (4) grow vegetable crops instead of or in addition to fruit crops ($p < 0.001$). No relationship was found to exist between cover cropping and farmers' concerns about climate-related risks, education level, or perceived self-efficacy. We conclude by suggesting that the importance of structural factors to farmers' decisions about cover crops should not be underestimated. Promoting and strengthening the market for organic food may be the most direct pathway toward increasing the number of farmers who use cover crops. Historically important entities in agricultural networks, including cooperative extension and conservation nongovernmental organizations, might enhance their impact on cover crop use by forming new partnerships with private crop consultants.

Key words: cover crops—crop consultants—organic farming—specialty crops

Experts agree that it is crucial, for the security of the world's food supply, the health of the natural environment, and the resiliency of cropping systems in the face of climate change, for sustainable agricultural practices to be widely used by farmers (Horrigan et al. 2002; Robertson 2015). Sustainable agriculture involves producing sufficient food to meet humanity's needs while conserving natural resources and enhancing the economic and social wellbeing of farmers and rural communities (Feenstra et al. 2021; Gold 2007). Cover crops—"crops grown primarily for the purpose of protecting and improving soil between periods of regular crop production" (Schnepf and Cox 2006)—are widely considered to be an important sustainable agricultural practice because their use can provide multiple ecosystem services (Blanco-Canqui et al. 2015) without compromising yields (Shelton et al. 2018; Wittwer and van der Heijden 2020). More specifically, cover crops build soil organic matter, improve soil structure, reduce erosion during heavy rains, and increase water infiltration (Kaspar and Singer 2011; Nair et al. 2015). Cover crops can suppress weeds, pests, and disease, and many also attract beneficial insects (Everts 2016; Finney et al. 2017; Robačer et al. 2016); these functions can enable farmers to decrease application of pesticides. Farms that use cover crops see less nutrient leaching because cover crops take up nitrogen (N) and water (Kaspar et al. 2012; Kladivko et al. 2014); decreased nutrient runoff can reduce the prevalence of hypoxic "dead zones" in water bodies like the Great Lakes and the Gulf of Mexico (Malone et al. 2014). Research largely suggests that, with careful management, cover crops present little risk of negatively impacting cash crop yield and quality (Daryanto et al. 2018; Schipanski et al. 2014). By conserving and improving natural resources in a way that is economically feasible for farmers, cover crops make valuable contributions not just to environmental health but also to the economic sustainability of farms and rural communities.

Encouraging farmers to use cover crops has become an important goal of agricultural agencies and sustainable farming organizations (Elliott 2020; Monast et al. 2018). Social science researchers (Bergtold et al. 2012; Dunn et al. 2016) have contributed to this effort by collecting data to answer a broad range of questions, including who is using cover crops, what kinds of cover crops are being used, and what characteristics of farm operations and farmers are associated with cover crop use. Answers to questions like these can give a detailed understanding of where progress needs to be made in expanding cover crops, and of what obstacles remain for many farmers. According to USDA, 15.4 million ac (6.2 million ha) were planted in cover crops in 2017, and while this number represents a 50% increase since 2012, it is still just 5.1% of harvested cropland (Wallander et al. 2021). Existing research suggests that

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farmers who plant cover crops are motivated by positive environmental values and prior experience with conservation programs and practices, and may also be relatively young and well-educated (Lichtenberg 2004; Long et al. 2013; Morton et al. 2017). But financial constraints and lack of technical knowledge represent significant impediments to experimenting with cover crops for many farmers (Roesch-McNally et al. 2018). Indeed, the possible agricultural, environmental, and economic benefits of cover crops are still far from fully realized on a national scale.

The overall number of studies taking on questions about cover crop use is indicative of the importance accorded to cover crops by sustainable agriculture advocates. Yet despite the growing robustness of the social science literature, there exists at least one population of farmers whose practices and views remain largely unexamined. Namely, far less research has been conducted on cover crop use by farmers who grow mainly specialty crops—fruits and vegetables, tree nuts, and horticultural and nursery crops (Johnson 2017)—compared to the much larger body of research on farmers who principally grow field crops like corn (*Zea mays*) and soybeans (*Glycine max*). Two recent reviews (Carlisle 2016; Prokopy et al. 2019) highlight 12 refereed studies, published in 2000 or later, that consider the causes and behavioral correlates of using cover crops (Roesch-McNally et al. 2017; David et al. 2015; Ulrich-Schad et al. 2017). Of these, only one—a survey of farmers in Michigan's "fruit belt" region—focuses on cover crop use among vegetable and fruit growers (Garbach and Morgan 2017). This Michigan-centered study, however, was interested in cover crops primarily as habitat for pollinators, and does not include data on what varieties or combinations of cover crops are used. The most recent census of agriculture found that 28.7% of vegetable and melon farms nationwide, and 12.4% of fruit and tree nut farms, include land planted in cover crops (USDA NASS 2019c). However, neither USDA data nor a recent survey of farmers with demonstrated interest in conservation practices (CTIC 2020) speak to what cover crops specialty crop growers are using, how cover crop use varies on specialty crop farms of different types, or what predicts cover crop usage among specialty crop farmers.

There are several reasons why it is important to look at cover crop use specifically by farmers who grow specialty crops. First, planting cover crops is projected to be an important climate change adaptation practice for specialty crop farmers. Climate change has brought intense heat and drought to the West, while farmers in the Midwest and Northeast face more frequent severe precipitation events (Morton et al. 2015), "false springs" followed by dramatic crop losses (Labe et al. 2017), and heightened pressure from pests that expand north and survive warmer winters (Bebber et al. 2013). Specialty crops are particularly vulnerable to climate-related stressors because their appearance, texture, and taste are highly sensitive to excess moisture, pests, and disease (Ahmed and Stepp 2016; Kistner et al. 2018). This vulnerability is arguably even more pronounced for certified organic growers, whose ability to use agricultural chemicals to deal with threats is severely restricted.

By reducing erosion and nutrient leaching, improving soil health, suppressing weeds, and inhibiting pests and disease, cover crops can help to buffer farms from the impacts of climate change (Morton et al. 2015). At the same time, different cover crops have properties that make them more or less suitable for performing specific agroecological services on farms (Clark 2007; Magdoff and Van Es 2009). The distinction between legume and nonlegume cover crops is particularly important. Legumes fix N, a necessary element for plant growth, from the atmosphere to the soil, making it available for use by crops; flowering legumes also attract pollinators and beneficial insects. But legumes, which break down quickly and have a relatively low carbon (C)-N ratio, add less organic matter to soil than do nonlegume cover crops. Grasses do not fix N, but rather scavenge N and other nutrients from soil following a harvest, thereby reducing nutrient leaching. Grasses break down posttermination and release stored N slowly, which, coupled with a high C-N ratio, results in relatively robust addition of organic matter to soil. Other cover crops include brassicas, which produce natural biofumegants that can suppress soil pests, and buckwheat (*Fagopyrum esculentum*), whose rapid growth can help to quickly condition soil. In sum, cover cropping is a complex practice whose impacts on farm ecology and operations depend on, among other things, which cover crops are used. Understanding how and why cover crops are used by specialty crop farmers specifically is critical to being able to evaluate the overall resilience of specialty crop agriculture to the warming climate.

Second, specialty crop farmers may be using cover crops in ways that are not captured by existing studies of field crop farmers, because specialty crop systems provide more windows for cover crop establishment than do field crop systems (Clark 2007). In addition to overwintering cover crops on fallow fields, vegetable growers can sow fast-growing cover crops in the period (or periods) between when early-season vegetables are harvested and late-season vegetables are planted. Similarly, cover crops can be planted on orchard floors in spring or late summer (Roper et al. 2021). By contrast, cover crops in field crop systems are mainly used to provide winter cover on fallow fields (Clark 2007); currently, relatively few field crop farmers sow cover crops prior to cash crop harvest (CTIC 2020). More flexible timing options and a greater range of growing windows for cover crop establishment may mean that specialty crop growers are using cover crops in different ways or for different reasons than field crop growers. But researchers have not yet systematically explored these possibilities.

Finally, consumers, as well as farmers, stand to benefit when agriculture produces a safe and secure food supply without degrading natural resources. This is especially true where specialty crops are concerned. Fruits and vegetables are critical to a healthy diet. Boosting consumption of fruits and vegetables, especially among disadvantaged social groups, is a central goal of contemporary food policy (Bowen et al. 2015). Cover crops contribute to sustainable agricultural systems not just because they benefit farms' natural capital, but also—indeed, especially—because these environmental benefits largely do not come at the expense of cash crop yield or farm revenue (Schipanski et al. 2014; Shelton et al. 2018). In other words, cover crops, when incorporated into specialty crop systems, help to make a crucial link in US food supply chains more resilient and secure. Yet, as detailed above, despite the strong connection between sustainable specialty crop agriculture and public health, what is known about cover crop use comes mainly from data on field crop farmers.

Considerations related to natural resource conservation, farmers' economic wellbeing, and food security make understanding how and why specialty crop farmers use cover crops all the more pressing. But the picture of cover crop usage among specialty crop farmers is far from complete. It is this gap in the literature that this study is intended to address. Drawing on data from specialty crop growers in two midwestern states—Michigan and Ohio—this study has two main goals. First, we seek to characterize cover crop use among this important group of farmers, focusing on types of cover crop used and use of multiple types. Second, we examine the relationship between cover crop use on vegetable and fruit farms and key social and economic factors, with particular attention to farmers' environmental values, adherence to organic principles, and sources of information.

Materials and Methods

Data. Data for this study come from a 2017 survey of Michigan and Ohio farmers growing vegetables and/or fruit crops for sale. Michigan and Ohio are well suited as sources of data for this study. Nationwide, sales from fruits and vegetables make up approximately 75% of all specialty crop sales (Johnson 2019), and a majority of farms classified as specialty crop farms in Michigan and Ohio grow primarily vegetable or fruit crops (USDA NASS 2019c). From 2012 to 2017, the share of cropland planted to cover crops increased from 6.5% to 10% in Michigan and from 3.5% to 7% in Ohio (Wallander et al. 2021). But both states, like the Midwest overall, lag behind most northeastern and Mid-Atlantic states in cover crop coverage.

The survey questionnaire was developed in consultation with cooperative extension specialists and pretested with farmers in both states. The USDA National Agricultural Statistics Service (NASS) was contracted to manage data collection for the survey, which took as its population frame 8,383 farm operations in Michigan and Ohio that reported harvesting at least 1 ac (0.4 ha) of vegetable and/or fruit crops in the most recent (2012) census of agriculture. The population frame was stratified into six categories, according to whether a farm was small (1 to 10 ac [0.4 to 4 ha]), medium (10.1 to 75 ac [4 to 30.3 ha]), or large (greater than 75 ac), and whether, within each size group, more area was in vegetable or fruit crops (see supplementary table S1). Between 325 and 600 farms were selected from each stratum for inclusion in the study, for a total initial sample of 3,000 farms.

The survey design methodology known as the "tailored design method" (Dillman et al. 2014) is widely seen as a state-of-the-art guide to survey research in fields ranging from public health and medicine to sociology and human ecology (Clendenning et al. 2004; Converse et al. 2008; Hoddinott and Bass 1986). According to the tailored design method, survey participation rates tend to be highest when respondents believe that the study is trustworthy, that benefits to participating will outweigh costs, and that taking the survey will be relatively easy (Dillman et al. 2014). The survey for this study was designed with these principles in mind, and was approved by the Institutional Review Board at Rutgers University. Multiple modes and points of contact were used to recruit potential respondents. Farm operators received the survey questionnaire first by mail in late January of 2017, and then a second time by mail about three weeks later. Each mailing was accompanied by a cover letter explaining the potential benefits of the study for agricultural experts and farmers; cover letters were signed by investigators affiliated with universities in Michigan and Ohio. In February and March, farm operators who had not returned a survey by mail were contacted by phone by survey enumerators and given the option of taking the survey over the phone.

When data collection closed in late March, 1,401 valid survey reports had been returned (the response rate was 46.7%). Of these valid reports, NASS classified 881 (62.9%) as usable because they were from active farmers who were currently growing vegetable or fruit crops, and 520 (37.1%) as not usable, because respondents were either no longer farming or no longer growing vegetable or fruit crops. The percentage of valid but nonusable reports for this study was similar to that of another recent study for which NASS surveyed farmers in the Midwest (Matts et al. 2016), where 40% of valid reports were not usable due to farm inactivity. If nonusable reports are excluded from the initial sample, then the response rate for valid, usable reports (881 as a percentage of 2,480) was 35.5%. All six sampling strata were substantially represented in the final sample of 881 usable reports (Schoolman 2020).

Models and Variables. This study uses two survey items on cover crops. First, respondents were asked if they planted cover crops on land used for vegetable and/or fruit crops. Second, respondents were asked what cover crops (if any) they used. Specifically, the survey asked about 11 cover crops: three legumes (vetch [e.g., *Vicia villosa*], clover [e.g., *Trifolium incarnatum*], and peas [e.g., *Pisum sativum*]); five nonleguminous grasses (rye [*Secale cereale*], barley [*Hordeum vulgare*], wheat [*Triticum aestivum*], sudan [*Sorghum bicolor*], and oats [*Avena sativa*]); two brassicas (radish [*Raphanus sativus*] and mustard [e.g., *Sinapsis alpa*]); and buckwheat; respondents also had the option of marking "other" if they used a cover crop not enumerated on the survey. All cover crops included on the survey help to control erosion, add organic matter to soil, suppress weeds, and potentially supply forage, to some degree. However, as noted earlier, only legume cover crops fix N in soil, while grasses and other nonlegumes also have properties that recommend them to farmers looking to accomplish specific agroecological goals (Clark 2007; Magdoff and Van Es 2009).

Data were analyzed in several ways. First, frequency distributions were generated to shed light on how many specialty crop farmers use cover crops, what kinds and how many cover crops are used, and how cover crop use varies across farm size, organic status, and other farm characteristics. Second, a logistic regression was conducted using a binary dependent variable for whether farmers planted cover crops in conjunction with vegetable and/or fruit crops. Third, because sowing multiple cover crop species can confer significant agroecosystem benefits (Franzluebbers et al. 2021; Hunter et al. 2019), a multinomial logistic regression was conducted using a four-category dependent variable for whether farmers planted one, two, or three or more kinds of cover crops; the reference group was not planting any cover crops.

Independent variables were included in regression models to explore the following four main questions about specialty crop farmers and cover crops:

1. Are farmers who practice organic agriculture more likely to plant cover crops? The foundational idea of organic agriculture is that soil health and quality are of paramount importance (Goulding et al. 2008; Reganold and Wachter 2016; Youngberg and DeMuth 2013). Cover crops are often promoted for their ability to help farmers manage nutrients and suppress pests and weeds without the aid

of chemical inputs (Robačer et al. 2016). Thus it is reasonable to expect that cover crops would be more widely used by farmers who endorse or follow organic principles. But researchers have not yet directly examined the strength of this relationship, particularly among specialty crop farmers, nor whether it depends on the nature of a farmer's connection to organic agriculture. The survey asked farmers to indicate if their farm was (1) certified organic or transitioning to certified organic, or (2) organic-in-practice, but not certified or transitioning. A three-level categorical variable was created based on this item. The reference group for this variable—which we call "nonorganic farms" in the rest of this paper—was comprised of farms that were neither certified organic, transitioning to certified organic, or organic-in-practice, according to the farm operator.

2. Are farmers who attach high importance to achieving agri-environmental goals when making farming decisions more likely to use cover crops? This question is directly relevant to understanding whether farmers who prioritize on-farm and off-farm natural resource conservation see cover crops as a way of making progress toward these goals (Dobbs and Pretty 2004; Mauchline et al. 2012). The survey asked farmers to rate the importance of a series of criteria for how they make decisions for their farm operation. Responses for these items were given on a 4-point scale, from 1 (not important) to 4 (very important). A scale variable (Cronbach's alpha = 0.796) measuring the importance of agri-environmental goals to farmers was created by averaging importance scores for six criteria that had a clear relationship to core agroecological services performed by cover crops: (1) minimize soil erosion, (2) maintain or increase soil organic matter, (3) minimize nutrient loss into waterways, (4) minimize the use of pesticides and fungicides, (5) maintain habitat for wildlife, and (6) consider the health of streams on/near your land to be your responsibility.
3. To what extent is cover crop use associated with specialty crop farmers' level of concern for how farm operations might be impacted by climate change and extreme weather? This question is particularly pressing given the potential for cover crops to help farmers address problems that are becoming more prevalent in the context of climate change, like soil erosion, nutrient leaching, and increased pest and pathogen threats (Kaspar and Singer 2011). The survey asked farmers to rate their level of concern for a range of problems that climate change and extreme weather are causing or exacerbating for farm operations in the Midwest. Responses for these items were also given on a 4-point scale, from 1 (not concerned) to 4 (very concerned). A scale variable (Cronbach's alpha = 0.748) was created by averaging concern scores for five problems that cover crops are most associated with potentially helping to address: (1) more frequent extreme rains, (2) increased weed or insect pressure, (3) higher incidence of crop disease, (4) changes in health or timing of pollinators, and (5) increased flooding.
4. What sources of information are associated with specialty crop farmers' use of cover crops? Survey respondents were asked to rate the influence, on their own farming decisions, of 13 different sources of information, on a 3-point scale of 1 (no influence), 2 (some influence), or 3 (strong influence). Based on these individual items, index variables (average scores across items) were created for two broad influence groups: (1) mainstream influences (major farm organizations, government agencies, and university cooperative extension; alpha = 0.738), and (2) sustainability and local food influences (nongovernmental organizations [NGOs] focused on sustainable farming, conservation and environmental issues, or local food; alpha = 0.721). The survey also included two items for private sector influences: (1) private crop or livestock consultant, and (2) sales representatives for seeds, crop varieties, pesticides, or fertilizers. An index variable based on both items, however, had a Cronbach's alpha of only 0.5, indicating relatively weak internal consistency. The two private sector influences were therefore included in regression models as dummy variables (1 = strong influence or some influence; 0 = no influence).

Table 1 summarizes component items for scale variables and reports Cronbach's alpha for the internal consistency of each scale. Table 2 summarizes component items for dummy variables. The agri-environmental goals, weather-related threats, and influences on farmers that we model in this study are all theoretically relevant to farmers' use of cover crops. But the variables that we build from our data are of course not exhaustive of the problems that farmers encounter, the goals they might have, or the influences that matter for their decision-making. We engage further with this issue of limitations to regression models later in this paper.

In addition to the above explanatory variables of primary interest, regression models include control variables for a range of theoretically relevant characteristics of farmers and farm operations (Prokopy et al. 2019). Larger farms typically have greater economic resources, and by definition have more land on which to experiment with conservation practices. USDA NASS (2019c) data suggest that specialty crop growers who grow primarily fruit crops may be less likely to use cover crops than those who grow primarily vegetable crops. Farmers who have a college degree, and farmers who have a strong sense of self-efficacy, may be more likely to employ conservation practices; the opposite may be true for older farmers (Prokopy et al. 2008, 2019).

With the findings of earlier studies in mind, regression models control for (1) area in vegetable and/or fruit crops, (2) whether the farmer has a four-year college degree, and (3) farmer age. A three-level categorical variable was created to characterize farmers as growing either only fruit crops (the reference category), only vegetable crops, or both fruit and vegetable crops. A binary measure of internalized self-efficacy was constructed based on whether farmers agreed with the statement "I have the knowledge and technical skills to deal with most weather-related threats to my farm operation"; the reference category comprised farmers who disagreed or were uncertain. Finally, government, extension and farm organization outreach regarding cover crops has often targeted farmers who grow row crops (Myers et al. 2019). For this reason, we included a binary measure of whether, in addition to specialty crops, a farm grew corn for grain, corn for silage, soybeans, or sugarbeets (*Beta vulgaris*).

Data analysis was conducted with Stata MP/15. The amount of missing data was relatively small; however, it is now widely agreed that multiple imputation of missing data is preferable to complete case analy-

Table 1
Scale variables and component items.

	N	Mean	sd	Not important (%)	Slightly important (%)	Important (%)	Very important (%)
Importance of agri-environmental goals (α = 0.796)	768	3.058	0.632				
Minimize soil erosion	824	3.187	0.848	5.6	11.5	41.5	41.4
Maintain or increase soil organic matter	822	3.193	0.820	4.4	12.7	42.4	40.8
Minimize nutrient loss into waterways	818	2.955	1.034	14.8	11.4	37.4	36.4
Minimize the use of pesticides and fungicides	831	3.211	0.781	2.4	14.9	41.9	40.8
Maintain habitat for wildlife	823	2.650	0.991	15.2	27.1	35.2	22.5
Consider the health of streams on/near your land to be your responsibility	815	3.110	0.902	7.6	12.9	40.4	39.1
Concern about climate change and extreme weather problems (α = 0.748)	765	2.364	0.693				
More frequent extreme rains	819	2.208	1.005	30.4	30.3	27.5	11.8
Increased weed or insect pressure	820	2.772	0.940	12.0	22.3	42.3	23.4
Higher incidence of crop disease	815	2.650	0.963	14.4	26.9	38.2	20.6
Changes in health or timing of pollinators	810	2.663	1.059	18.9	21.9	33.3	25.9
Increased flooding	810	1.557	0.919	67.9	14.8	11.0	6.3
	N	**Mean**	**sd**	**No influence (%)**	**Some influence (%)**	**Strong influence (%)**	
Mainstream public and farm organization influences (α = 0.738)	776	1.771	0.572				
Major farm organizations with a broad focus (Farm Bureau, Vegetable Growers, etc.)	793	1.651	0.687	47.2	40.6	12.2	
Government agriculture or conservation agencies	796	1.702	0.681	42.5	44.9	12.7	
University Extension (staff, online info, etc.)	813	2.002	0.754	28.3	43.2	28.5	
Sustainability and local food influences (α = 0.721)	756	1.513	0.510				
Farm organizations focused on sustainable farming	778	1.602	0.668	50.1	39.6	10.3	
Conservation or environmental groups	788	1.475	0.610	58.6	35.3	6.1	
Farm organizations focused on local food	777	1.501	0.642	58.0	33.9	8.1	

Table 2
Component items for dummy variables.

	N	Mean	sd	Dummy = 0 No influence (%)	Dummy = 1 Some influence (%)	Strong influence (%)
Private crop or livestock consultant	764	1.484	0.734	66.0	19.6	14.4
Sales representatives for seeds, crop varieties, pesticides or fertilizers	802	1.860	0.726	34.3	45.4	20.3
				Dummy = 0		**Dummy = 1**
	N	**Mean**	**sd**	**Disagree (%)**	**Neither agree nor disagree (%)**	**Agree (%)**
Self-efficacy: "I have the knowledge and technical skills to deal with most weather-related threats to my farm operation"	824	2.470	0.666	9.7	33.6	56.7

sis (Allison 2010; Lang and Little 2018). We used multiple imputation by chained equations (MICE) to generate 20 completed data sets (White et al. 2011); variable means and regression results showed little change after imputation.

Results and Discussion

Survey Sample. The survey sample was broadly representative of the known population of specialty crop growers in Michigan and Ohio. Across both states, the sample was 86.9% male and 13.1% female, and the average respondent age was 57.5 years. According to USDA, principal operators growing specialty crops in Michigan were 87.3% male and 12.7% female in 2012, with an average age of 56.8 years, while principal operators growing specialty crops in Ohio were 86.4% male and 13.6% female, with an average age of 55.4 years (USDA NASS 2015). In the sample, 6.0% of farms were certified organic. According to USDA, 4.1% of farms growing vegetables in Michigan and Ohio in 2017 were selling certified organic vegetables (USDA NASS 2019c, 2019b; identical calculations cannot be made for farms growing any kind of fruit, because of how USDA breaks out organic fruit crops).

Smaller farms were underrepresented on the survey, however. Among farms in the sample that grew vegetable crops, 69% had less than 25 ac (10.1 ha) in vegetables. According to USDA, 82% of Michigan farms and 93% of Ohio farms growing vegetables in 2017 had less than 25 ac in vegetables (USDA NASS 2019d). Among farms in the sample that grew fruit crops, 61.7% had less than 25 ac in fruit. According to USDA, 76.4% of Michigan farms and 95.7% of Ohio farms with orchards had less than 25 ac in orchards (USDA reports size categories for orchards, but not for berries or all fruit) (USDA NASS 2019d). The underrepresentation of smaller farms has been observed in other studies where NASS was contracted to collect survey data from farms in the Midwest (Garbach and Morgan 2017; Matts et al. 2016).

The survey sample also included a relatively high proportion of farmers who used cover crops, as compared with data from the census of agriculture. Sixty-five percent of survey respondents reported planting at least one cover crop (table 3). According to USDA, 33.7% of vegetable and melon farms in Michigan and Ohio planted land to cover crops in 2017, as well as 18.3% of fruit and tree nut farms (USDA NASS 2019a). The proportion of farmers planting cover crops in this study was comparable, however, to that in two other recent studies that also relied on survey data collected by NASS. In these studies, 66% of farmers growing primarily corn, cotton (*Gossypium hirsutum* L.), peanuts (*Arachis hypogea* L.), and soybeans in Alabama, and 49% of apple (*Malus domestica*), cherry (*Prunus avium*), and berry growers in Michigan (equivalent to fruit-only growers in our study), reported using cover crops (Bergtold et al. 2012; Garbach and Morgan 2017). Cover crop users may be more likely than non-cover crop users to respond to surveys that are not part of the actual census of agriculture. In analyses of survey data below, our priority is first to explore what kinds of and how many cover crops are used on different types of specialty crop farms. Then, we examine factors that might explain why some specialty crop farmers use cover crops, while others do not.

Cover Crop Use. Table 3 and table 4 report frequency distributions for cover crop use; chi-square significance levels are given for each comparison across categories of a variable. Table 5 reports descriptive statistics for variables included in regression models. Table 6 reports regression results. Odds ratio coefficients on table 6 can be interpreted as indicating whether the odds of using cover crops increase (odds ratio > 1) or decrease (odds ratio < 1) by a statistically significant amount, based on change in an independent variable. Multicollinearity was low in regression models (variance inflation factors [VIFs] < 5), and findings were robust to the presence of several very large farms.

The first main finding of this study is that cover crop use differs significantly across nonorganic, organic-in-practice, and certified organic farms. This is true first with respect to whether farms use cover crops at all. Sixty-two percent of nonorganic farms used cover crops in conjunction with vegetable and fruit crops, versus 73.1% of organic-in-practice farms and nearly all certified organic farms ($p < 0.001$) (table 3). Logistic regression likewise indicates that the odds of using cover crops were over six times greater for certified organic farmers than for nonorganic farmers (odds ratio = 6.168; $p < 0.01$), and 78% greater for organic-in-practice farmers (odds ratio = 1.780; $p < 0.05$), controlling for other factors (table 6).

Importantly, the multinomial regression model also indicates that all multispecies cover cropping was more likely on certified organic farms, and using three or more cover crops was more likely on organic-in-practice farms (the odds ratio coefficients for each of these effects were significantly greater than 1). Multispecies cover cropping, in particular utilizing three or more kinds of cover crops, has been shown to confer significant agroecosystem benefits, compared to not using cover crops at all or using just one cover crop species (Chu et al. 2017; Franzluebbers et al. 2021; Hunter et al. 2019). Benefits of multispecies cover cropping have been found to include better water and nutrient retention, higher soil biological activity, and comparable or greater cash crop yields. Strong relationships between organic farms and complex, multispecies cover cropping suggest that cover crops have become an essential part of organic cropping systems.

Arguably the most crucial difference between organic and nonorganic farms, however, relates not to whether cover crops are used, but rather to what kinds of cover crops are used, and the agroecological functions that these cover crops are understood to serve. Among all nonorganic farmers who responded to the survey, a majority (54%) planted grass cover crops, especially cereal rye or brassicas. Grasses and brassicas scavenge N left over from fertilizer application, control erosion, and, upon termination, build substantial soil organic matter due to a high C-N ratio and relatively slow rate of decomposition (Clark 2007). In contrast, less than 17% of farmers managing nonorganic farms planted legume cover crops like clover varieties and vetch. The prime function accomplished by legume cover crops is not to scavenge N, but rather to produce plant-available N through atmospheric fixation. By building soil N, legume cover crops can reduce, with careful management, the need for external fertilizer inputs (Holmes et al. 2019; Shelton et al. 2018). However, legume cover crops have a low C-N ratio and break down quickly; legumes therefore add less organic matter to soil than do nonlegume cover crops (Clark 2007). It seems likely that most nonorganic farmers, whose use of legume cover crops is relatively low, view cover cropping mainly as a way to build soil organic matter and reduce erosion and nutrient loss, but not to substitute for fertilizer as a source of new N.

Table 3
Cover crop use by farm size and organic status.

	Farms		Farm size							Farm organic status						
	All farms (n = 881)		Small (<5 ac) (n = 175)		Medium (5 to 24.9 ac) (n = 312)		Large (25+ ac) (n = 394)			Nonorganic farms (n = 709)		Organic-in-practice farms (n = 119)		Certified organic farms (n = 53)		
Crop	*N*	%	*N*	%	*N*	%	*N*	%	Chi-square sig. level	*N*	%	*N*	%	*N*	%	Chi-square sig. level
Cover crop(s), any type	572	64.9	101	57.7	182.0	58.3	289	73.4	***	436	61.5	87	73.1	49	92.5	***
Types of cover crops																
Legumes	207	23.5	47	26.9	93.0	29.8	67	17.0	***	120	16.9	51	42.9	36	67.9	***
Vetch	51	5.8	13	7.4	24.0	7.7	14	3.6	*	24	3.4	13	10.9	14	26.4	***
Clover	175	19.9	37	21.1	80.0	25.6	58	14.7	**	101	14.2	43	36.1	31	58.5	***
Peas	55	6.2	12	6.9	29.0	9.3	14	3.6	**	16	2.3	20	16.8	19	35.8	***
Grasses	497	56.4	77	44.0	157.0	50.3	263	66.8	***	383	54.0	71	59.7	43	81.1	***
Rye	430	48.8	64	36.6	135.0	43.3	231	58.6	***	334	47.1	59	49.6	37	69.8	**
Barley	34	3.9	5	2.9	8.0	2.6	21	5.3	n.s.	21	3.0	7	5.9	6	11.3	**
Wheat	106	12.0	16	9.1	31.0	9.9	59	15.0	n.s.	75	10.6	21	17.6	10	18.9	*
Sudan	79	9.0	3	1.7	19.0	6.1	57	14.5	***	60	8.5	13	10.9	6	11.3	n.s
Oats	168	19.1	29	16.6	60.0	19.2	79	20.1	n.s.	112	15.8	30	25.2	26	49.1	***
Brassicas	162	18.4	21	12.0	52.0	16.7	89	22.6	**	115	16.2	29	24.4	18	34.0	**
Radish	143	16.2	16	9.1	47.0	15.1	80	20.3	**	101	14.2	26	21.8	16	30.2	**
Mustard	35	4.0	10	5.7	7.0	2.2	18	4.6	n.s.	21	3.0	9	7.6	5	9.4	**
Buckwheat	107	12.1	27	15.4	44.0	14.1	36	9.1	*	54	7.6	29	24.4	24	45.3	***
Other	71	8.1	12	6.9	17.0	5.5	42	10.7	*	54	7.6	10	8.4	7	13.2	n.s.

*** $p < 0.001$. ** $p < 0.01$. * $p < 0.05$. n.s. = not significant.

Cover crops that build N—legumes—are significantly more widely used on certified organic farms and farms described as organic-in-practice (table 3). Legume cover crops are also used by nearly two-thirds of farms that plant three or more cover crops; as already noted, multispecies cover cropping is disproportionately practiced on organic farms. The USDA National Organic Program (NOP) prohibits the use of most synthetic fertilizers, which are widely used to supply nutrients to nonorganic crops. In place of synthetic fertilizer, NOP directs organic farmers to manage soil fertility and nutrients in a way that maintains or improves soil organic matter (Coleman 2012; Goldammer 2017). NOP encourages but does not specifically require organic farmers to incorporate legume cover crops into their plans for how to accomplish this goal. Other means of supplying N to crops are also available to organic farmers, including manure, compost, plant and animal-based meal, and some kinds of mineral fertilizer (Gaskell and Smith 2007; Roberson 2010). In theory, organic farmers could mainly or exclusively be using NOP-approved inputs to provide organic crops with N, rather than making cover crops an important part of this process.

Survey results would appear to suggest, however, that what NOP envisions for organic agriculture is indeed taking place on many organic specialty crop farms, whether officially certified as such or not. Among respondents to the survey, over two-thirds (67.9%) of certified organic farmers were using legume cover crops—a percentage four times greater than that (16.9%) for conventional farms. The percentage of organic-in-practice farms using legume cover crops (42.9%) was over 2.5 times greater than that for nonorganic farms. In contrast, nearly the same percentage of organic-in-practice and nonorganic farms reported using grass cover crops (59.7% and 54%, respectively). The fact that legume cover crops are used several times more frequently on certified organic and organic-in-practice farms suggests that managers of these farms are following organic principles by employing cover crops to build N into soil (Heckman 2005; Youngberg and DeMuth 2013).

The second main finding of this study is that farmers who prioritize making progress toward agri-environmental goals when making farming decisions were significantly more likely to use cover crops. Each additional point on the "importance of agri-environmental goals" scale was associated in the logistic model with a 58.5% increase in the odds of using cover crops ($p < 0.01$), and, in the multinomial model, with a 53.7% increase in the odds of using two cover crops ($p < 0.05$) and a 126.8% increase in the odds of using three or more cover crops ($p < 0.001$). This finding broadly echoes overall patterns in the existing literature on farmers and agricultural conservation (i.e., the employment of best management practices for soil and water conservation on agricultural land). A recent comprehensive review of quantitative studies (Prokopy et al. 2019) finds moderate support for the hypothesis that holding positive environmental values—for instance, subscribing to the New Ecological Paradigm (Dunlap et

Table 4

Cover crop use by kinds of specialty crops and number of cover crops grown.

	Kinds of specialty crops grown							Number of cover crops grown						
	Fruit crops only (n = 346)		Vegetable crops only (n = 255)		Fruit and vegetable crops (n = 280)			One cover crop (n = 224)		Two cover crops (n = 127)		Three or more cover crops (n = 221)		
	N	%	N	%	N	%	Chi-square sig. level	N	%	N	%	N	%	Chi-square sig. level
Cover crop(s), any type	164	46.4	192	75.3	216	77.1	***							
Types of cover crops														
Legumes	42	12.1	73	28.6	92	32.9	***	21	9.4	41	32.3	145	65.6	***
Vetch	6	1.7	22	8.6	23	8.2	***	0	0.0	2	1.6	49	22.2	***
Clover	38	11.0	60	23.5	77	27.5	***	21	9.4	36	28.4	118	53.4	***
Peas	5	1.5	25	9.8	25	8.9	***	0	0.0	5	3.9	50	22.6	***
Grasses	127	36.7	177	69.4	193	68.9	***	166	74.1	119	93.7	212	95.9	***
Rye	116	33.5	147	57.7	167	59.6	***	136	60.7	98	77.2	196	88.7	***
Barley	2	0.6	19	7.5	13	4.6	***	3	1.3	9	7.1	22	10.0	***
Wheat	17	4.9	46	18.0	43	15.4	***	15	6.7	29	22.8	62	28.1	***
Sudan	33	9.5	11	4.3	35	12.5	**	4	1.8	16	12.6	59	26.7	***
Oats	31	9.0	68	26.7	69	24.6	***	8	3.6	23	18.1	137	62.0	***
Brassicas	29	8.4	59	23.1	74	26.4	***	7	3.1	19	15.0	136	61.5	***
Radish	24	6.9	55	21.6	64	22.9	***	3	1.3	17	13.4	123	55.7	***
Mustard	6	1.7	8	3.1	21	7.5	**	4	1.8	2	1.6	29	13.1	***
Buckwheat	13	3.8	33	12.9	61	21.8	***	6	2.7	11	8.7	90	40.7	***
Other	40	11.6	15	5.9	16	5.7	***	24	10.7	6	4.7	41	18.6	***

*** $p < 0.001$. ** $p < 0.01$, * $p < 0.05$. n.s. = not significant.

al. 2000)—is predictive of employing a wide range of agricultural conservation practices. Two recent studies find that row crop farmers with a strong conservationist or stewardship identity are more likely to use cover crops (Morton et al. 2017; Roesch-McNally et al. 2017). Cover cropping by specialty crop farmers—the subject of this study—would therefore appear to be another instance where positive environmental values are relevant to understanding why farmers engage in agricultural conservation.

While not unexpected in the context of the larger literature, this study's findings regarding specialty crop farmers' cover cropping and agri-environmental goals are important. Specialty crops are a distinct agricultural sector, and farmers who specialize in specialty crops are a distinct population (Johnson 2014). Indeed, as noted earlier, enhancing domestic production of fruits and vegetables, which generate most of the revenue for specialty crop farms, has become a central goal for farm and food policy (Johnson 2014). No previous study, to the best of our knowledge, has examined the relationship between positive environmental values and cover cropping in specialty crop agriculture. Regression results strongly suggests that specialty crop farmers who highly value agricultural conservation and environmental sustainability understand the relevance of cover cropping to achieving these goals, and can and do act on this knowledge. In light of the growing importance of the specialty crop sector, it is valuable to have clear evidence of a relationship between environmental values and a key conservation practice for farmers in this sector, even if it largely conforms to expectations based on studies of other kinds of farms.

The third main finding of this study is that whether a farmer uses cover crops is not significantly related to his or her level of concern about problems related to climate change and extreme weather. There is ample precedent in the literature for this finding, as well: most existing studies find no statistically significant association between agricultural conservation practices and concern about increasingly impactful consequences of climate change or perceptions of overall environmental quality (Prokopy et al. 2019). Exceptions exist: one recent study finds that strong concern about extreme rains and erosion—but not flooding—may make row crop farmers in the Midwest more likely to plant cover crops (Roesch-McNally et al. 2017). Overall, however, existing studies suggest that simply perceiving climate change and extreme weather as posing serious risks for one's farm operation is relatively unimportant as a predictor of cover cropping. In the case of specialty crop farmers in Michigan and Ohio, this conclusion is supported by our regression models, as well.

There are at least two ways to interpret the finding that specialty crop farmers' perceptions of climate vulnerability are not associated with greater use of cover crops. The first would be to take this finding as an especially pointed challenge to one theoretically important hypothesis about how and when agricultural actors will respond to the climate crisis. Specifically, it is not infrequently propounded that farmers, like actors in other areas of society, will adopt and support sustainable practices when they see how climate change is impacting their personal livelihood (Bottemiller Evich 2019; Fierros-González and López-Feldman 2021; Sorvali et al. 2021; Zahran et al. 2006). Earlier in this paper, we highlighted reasons why climate change may prove particularly problematic

Table 5
Descriptive statistics for variables included in regression models.

	Data pre-imputation			Data post-imputation*	
	N	Mean	sd	Mean	sd
Farm organic status					
Nonorganic	881	0.805	0.397	0.805	0.397
Organic-in-practice	881	0.135	0.342	0.135	0.342
Certified organic	881	0.060	0.238	0.060	0.238
Importance of agri-environmental goals	768	3.058	0.632	3.042	0.637
Concern about climate change and extreme weather problems	765	2.364	0.693	2.372	0.694
Crop consultant influence	764	0.340	0.474	0.347	0.476
Agricultural retailer influence	802	0.657	0.475	0.655	0.476
Mainstream public and farm organization influences	776	1.771	0.572	1.790	0.579
Sustainability and local food influences	756	1.513	0.510	1.541	0.524
Specialty crop type					
Fruit crops only	881	0.393	0.489	0.393	0.489
Vegetable crops only	881	0.289	0.454	0.289	0.454
Vegetable and fruit crops	881	0.318	0.466	0.318	0.466
Farm size					
Small (<5 ac)	881	0.199	0.399	0.199	0.399
Medium (5 to 24.9 ac)	881	0.354	0.479	0.354	0.479
Large (>25 ac)	881	0.447	0.497	0.447	0.497
Row crops on farm	881	0.233	0.423	0.233	0.423
Age	853	57.838	12.786	57.882	12.765
Education (college degree)	865	0.386	0.487	0.386	0.487
Self-efficacy	824	0.567	0.496	0.567	0.496

**N* = 881 for all variables post-imputation.

for specialty crop farmers, including outsize impacts on the appearance and taste of fresh produce and limited access to crop insurance. Thus, if any farmers would be likely to adopt practices like cover cropping simply based on perceptions of climate risk, it stands to reason that this group would include specialty crop farmers, for whom these risks may objectively be relatively high. That this is not the case can be seen as a datapoint in support of an alternative proposition. Namely, farmers in general may be unlikely to adopt cover crops, or other sustainable farming practices, purely based on concern about environmental problems related to climate change.

It is also possible, however, to interpret the third finding for this study as indicative of something very different. The survey asked farmers about present concerns, views and practices. Strictly speaking, then, what survey results reveal is that farmers' concerns about climate risks *at the time of the survey* were not related to cover crop use *at that time*. These results do not rule out the possibility that at least some survey respondents may have been highly concerned about climate-related problems *at some point in the past*, and started using cover crops in part because of these concerns. By the time of the survey, however, these respondents' concerns may have declined, precisely because of the conviction that cover crops had made their farms more resilient. In other words, concern about climate-related problems may have influenced some farmers' original decision to use cover crops, but using cover crops has now alleviated these concerns.

These two interpretations of the finding for climate change concerns are not mutually exclusive. Survey data for this study do not offer a way to adjudicate between them, however. Future research might find it useful to specifically gather retrospective data on the past concerns of farmers, and how these concerns may have changed over time in response to cover cropping or other conservation agriculture practices. Longitudinal surveys and qualitative fieldwork (Ranjan et al. 2019) would be especially well-matched to this research goal.

The fourth main finding of this study is that only one set of influences had a positive relationship to cover crop use. Specifically, reporting that a private crop consultant had some measure of influence on one's farming decisions was associated with a 95.4% increase in the odds of using cover crops in the logistic model ($p < 0.01$), and, in the multinomial model, with a 63.3% increase in the odds of using one cover crop ($p < 0.05$) and a 197.3% increase in the odds of using three or more cover crops ($p < 0.001$). Influence from agribusiness sales representatives or mainstream public agencies and civil society NGOs had no relationship to cover crop use. Influence from sustainability and local food organizations was associated with a lower likelihood of using two or more cover crops, but otherwise no other coefficients for this variable were statistically significant.

Among studies of conservation agriculture practices, it has been relatively uncommon for researchers to separate out and assess the influence on farmers of different categories of social actors (Prokopy et al. 2019). Moreover, among studies that have raised these questions, no consensus on the relative importance of different influences has been reached. A recent study by Lee et al. (2018) finds that Iowa row crop farmers strongly influenced by private sector actors were less likely to use cover crops, while public sector and NGO influences had a positive impact on cover crop use. It is notable, however, that Lee's study does not examine the potential impact of crop advisors separately from that of other private sector actors. In a separate study focused entirely on the role of crop advisors, Eanes et al. (2017) find that farmers who use an independent or retail-affiliated crop advisor are substantially more likely to pursue a range of conservation strategies, including cover cropping. Eanes's study, however, does not control for confounding factors that might account for or detract from this relationship. Other studies have simply found no association between cover cropping and farmers' relationships with different groups of actors, including government agencies, cooperative extension, private sector representatives, or other farmers (Arbuckle and Roesch-McNally 2015; Dunn et al. 2016; Garbach and Morgan 2017; but see Roesch-McNally et al. 2017).

Given the divergent findings of existing studies, additional research into how farmers respond to outside influence around cover

Table 6

Regression models.

	Logistic model		Multinomial model					
	Do farms grow cover crops? (binary dependent variable)		Do farms grow one cover crop? (ref. group is no cover crops)		Do farms grow two cover crops? (ref. group is no cover crops)		Do farms grow three or more cover crops? (ref. group is no cover crops)	
	Coef.	Odds ratio	Coef.	Odds ratio	Coef.	Odds ratio	Coef.	Odds ratio
Farm organic status								
Organic-in-practice	0.576*	1.780*	−0.014	0.986	0.702	2.019	1.129***	3.092***
	(0.268)		(0.341)		(0.366)		(0.331)	
Certified organic	1.819**	6.168**	1.209	3.350	1.392*	4.022*	2.495***	12.124***
	(0.559)		(0.628)		(0.697)		(0.596)	
Importance of agri-environmental goals	0.461**	1.585**	0.304	1.355	0.430*	1.537*	0.819***	2.268***
	(0.149)		(0.172)		(0.213)		(0.204)	
Concern about climate change and extreme weather problems	0.201	1.223	0.182	1.200	0.361	1.435	0.112	1.118
	(0.140)		(0.161)		(0.189)		(0.175)	
Crop consultant influence	0.670**	1.954**	0.490*	1.633*	0.534	1.706	1.090***	2.973***
	(0.209)		(0.235)		(0.284)		(0.267)	
Agricultural retailer influence	0.033	1.034	−0.013	0.987	−0.010	0.990	0.134	1.143
	(0.200)		(0.231)		(0.282)		(0.266)	
Mainstream public and farm organization influences	0.232	1.261	0.181	1.198	0.495	1.641	0.137	1.147
	(0.208)		(0.240)		(0.283)		(0.273)	
Sustainability and local food influences	−0.225	0.798	−0.234	0.791	−0.680*	0.507*	0.047	1.049
	(0.218)		(0.255)		(0.310)		(0.275)	
Specialty crop type								
Vegetable crops only	1.181***	3.256***	1.099***	3.001***	1.038***	2.825***	1.492***	4.444***
	(0.222)		(0.253)		(0.312)		(0.297)	
Vegetable and fruit crops	1.424***	4.153***	1.126***	3.083***	1.392***	4.024***	1.932***	6.900***
	(0.213)		(0.248)		(0.297)		(0.283)	
Farm size								
Medium (5 to 24.9 ac)	0.020	1.021	−0.043	0.958	−0.206	0.814	0.324	1.382
	(0.232)		(0.274)		(0.332)		(0.317)	
Large (>25 ac)	0.834**	2.303**	0.750*	2.116*	0.659	1.933	1.164***	3.204***
	(0.255)		(0.293)		(0.353)		(0.348)	
Row crops on farm	0.596**	1.814**	0.397	1.487	0.775**	2.171**	0.711**	2.036**
	(0.231)		(0.264)		(0.295)		(0.273)	
Age	−0.018*	0.982*	−0.006	0.994	−0.019*	0.981*	−0.035***	0.966***
	(0.007)		(0.008)		(0.010)		(0.009)	
Education (college degree)	−0.158	0.854	−0.233	0.792	−0.210	0.811	0.016	1.016
	(0.171)		(0.199)		(0.241)		(0.222)	
Self-efficacy	0.191	1.210	0.314	1.369	0.193	1.213	−0.002	0.998
	(0.174)		(0.202)		(0.240)		(0.221)	
Constant	−1.896**	0.150**	−2.480***	0.084***	−3.129***	0.044***	−4.115***	0.016***
	(0.654)		(0.752)		(0.918)		(0.876)	
Observations	881	881	881	881	881	881	881	881
Pseudo R^2	0.184		0.134		0.134		0.134	

Note: Standard errors in parentheses.
*** $p < 0.001$. ** $p < 0.01$. * $p < 0.05$.

crops is clearly needed. With this proviso in mind, the results of this study can be seen as providing important support for earlier research into the role of crop advisors specifically (Eanes et al. 2017). Namely, we find that even after controlling for other factors, influence by private crop consultants is positively associated with cover crop use, including multispecies cover cropping. We discuss potential interpretations and implications of this finding, as well as its limitations, at greater length in the conclusion to this paper.

Finally, there were a number of notable findings for variables included in regression models as controls (table 6). Farms with 25 ac (10.1 ha) or more in specialty crops were more likely to use cover crops than farms with fewer than 5 ac (2 ha), but there was no significant difference in the likelihood of cover cropping on medium-sized versus small farms. It may be that 25 ac is close to an important cutoff point for when a farm's area is large enough to affect the probability of cover cropping. Younger farmers in this study were significantly more likely to use cover crops; other studies have also found that younger farmers are more open to experimentation and making changes to established cropping systems (Barbercheck et al. 2014). There was a strong, positive relationship across models between growing row crops—in addition to specialty crops—and cover crop use. We speculated earlier that since farmers growing row crops have been the target of significant cover crop advocacy, it would be reasonable to expect that farmers who grow both specialty crops and row crops would be more likely to plant cover crops on land used for the former. Farmers with relatively diverse cash crop operations may also be more willing or able to incorporate cover crops into existing cropping systems. Farmer education and perceived self-efficacy were not related to cover crop use in this study.

Regression models also indicated that farmers who grew either only vegetable crops, or both vegetable and fruit crops, were significantly more likely to use cover crops than farmers who grew only fruit crops. There are at least two possible explanations for this finding. First, cover cropping can be associated with costs to farm operations as well as benefits. Cover crops can compete with cash crops for water and nutrients (Snapp et al. 2005). Many cover crops have the potential to provide habitat for insect and animal pests (Wiman et al. 2009), and some, like rye, generally require termination by herbicide (Rees et al. 2021). Risks associated with cover crops may be especially worrisome for growers of perennial fruit crops, because orchard trees and bushes exist side-by-side with cover crops as they grow, whereas cover crops can be grown and terminated in-between plantings of annual vegetable crops. Evidence suggests that cover cropping is, on balance, beneficial for most farms, and that risks can be minimized by managing cover crops according to regional ecology, climate, and seasonal conditions (Daryanto et al. 2018; Schipanski et al. 2014). These overall findings are echoed in studies looking specifically at cover crop risks for orchard farms (Nordell and Nordell 2001; Rudolph et al. 2020; Wiman et al. 2009). But persistent concerns about competition and pest habitat from cover crops may be part of the reason why orchard growers appear not to use cover crops to the same extent as vegetable growers.

It is also possible, however, that the relatively low proportion of fruit-only growers who use cover crops may be, at least in part, an unintentional artifact of survey design. On the survey, farmers were asked whether they "plant cover crops," and if so, "which cover crops do you generally use." But there are also a small number of cover crop species that are not regularly "planted," because they are themselves long-lived perennial plants. Perennial crops—such as red clover—may be favored by orchard farmers, who can leave them as strips between orchard rows (Clark 2007). If long-lived perennial cover crops are indeed disproportionately used on fruit-only farms, then their use may be underreported on this survey.

As we have emphasized throughout this paper, little research exists on cover crop use on specialty crop farms. In reporting and discussing survey results, we have noted that additional data would be useful in at least two areas. First, data on past concerns about problems related to climate change would shed light on whether cover crops may help to alleviate these concerns over time. Second, survey items specifically about red clover and other perennial covers may give a fuller perspective on the practices of orchard farmers. Persistent gaps in cover cropping between orchard farms and other specialty crop farms may signal a need for communication about cover crop risks and benefits that is tailored to the trade-off considerations of perennial fruit growers.

Future research could build on the present study in other ways, as well. There were several areas where NASS protocols and concerns over survey length limited items on the survey. Future surveys might find it useful to gather additional data on (1) agri-environmental goals like improving water filtration and increasing nutrient availability; (2) concerns for agri-environmental problems like poor soil health and loss of soil organic matter; (3) influences on farmers related to specific agencies or conservation groups; (4) additional distinctions between cover crop species, such as crimson clover (*Trifolium incarnatum*) and berseem clover (*Trifolium alexandrinum*), which are both annual legumes but with somewhat different properties; and (5) participation in public and NGO-funded conservation programs for private lands, including the USDA Conservation Reserve Program and the USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP). Participation in conservation programs, in particular, was not covered on the survey for this study, and may well facilitate cover crop use by specialty crop farmers (Zhong et al. 2016). Finally, as we discuss below, greater attention is needed to the role of private crop advisors in farmer decision-making.

Summary and Conclusions

According to a recent review of nearly 100 studies, research into why farmers adopt agricultural conservation practices has generally attached greater theoretical significance to "social-psychological" characteristics of farmers than to larger social structures that limit and channel farmer agency (Prokopy et al. 2019). This, the review's authors conclude, is a mistake, because "farmers … make decisions in complex contexts within which factors such as markets, policies and programs, and other social institutions can facilitate or constrain behavioral change" (Prokopy et al. 2019). Moreover, structure and context have often shaped agriculture in ways leading to natural resource degradation. In particular, "social structural factors such as subsidies and publicly funded research priorities have driven major increases in specialization, monoculture … [and] dependence on purchased inputs [such as] synthetic fertilizers and pesticides" (Prokopy et al. 2019).

The present study is arguably the first to focus on cover crop use specifically by specialty crop farmers. Study results illustrate the importance of considering both social-psychological characteristics of farmers and indications of the larger structural context in which farmers and farms are embedded. Among survey respondents, younger farmers and farmers committed to agri-environmental goals were more likely to use cover crops. The variable with the strongest relationship to cover crop use, however, was farm organic status. Crop consultant influence and specialty crop type were also positively related to using cover crops. To conclude this paper, we would argue that these three factors—organic status, crop consultant influence, and specialty crop type—are prime examples of how larger economic, social, and environmental forces can shape how farmers think about agricultural conservation. Moreover, these factors all illustrate the potential for social structure to play an environmentally positive role in the future of specialty crop agriculture, rather than necessarily leading farmers to adopt practices that harm the environment.

Arguably the most significant example, in this study, of structural factors facilitating the development of sustainable agriculture, is the substantial, positive relationship between cover cropping and organic agriculture. As with any agricultural conservation practice, cover cropping entails risks and imposes costs, especially in the short term, as farmers learn a new technology, invest capital, and experience setbacks. The organic movement began to popularize the idea of food produced without agricultural chemicals in the 1970s (Youngberg and DeMuth 2013). The NOP formalized the US market for organic farm products in 2001. Since then, certified organic agriculture has grown to encompass 6% (by value) of all food sold in the United States (Watrous 2021), and many more farmers are producing organic food for local markets without seeking NOP certification (Veldstra et al. 2014).

Results from this study are consistent with the idea that the prospect of access to the organic market has led farmers to adopt cover crops. Moreover, findings suggest that increasingly widespread demand for organically grown local food (Schoolman et al. 2021) has created incentives for farmers not just to use cover crops, but also to practice multispecies cover cropping and to use legume cover crops to build N into soil. If this dynamic persists, then future expansion of the market for organic food may broaden still further the circle of farmers for whom cover crops are integral to farm operations. In sum, the relationship between cover crops and farm organic status constitutes strong support for the contention that the effect of large-scale social structures on agricultural conservation can equal or outweigh that of the values, views, and resources of individual farmers.

Two other findings from this study point to the potential for structural factors to move agriculture in a more sustainable direction. One valid interpretation of our regression results is that private crop consultants may be encouraging farmers not just to use cover crops, but also to practice environmentally beneficial *multispecies* cover cropping. Crop advisors, whether independent or affiliated with a retail business for agricultural supplies, are a relatively recent addition to the network of actors to whom farmers may turn for expert advice (Eanes et al. 2017). In fact, the emergence of crop consultants in agricultural networks is itself a response to structural forces. Longstanding, historically important public and civil society entities, like cooperative extension and conservation NGOs, face limited funding and reach and do not always have the full confidence of farmers (Mase et al. 2015; Prokopy et al. 2015). Private crop advisors, according to Eanes and others, have emerged to fill a market niche: they are viewed as paid agents acting in service of the farmer's own interest, and not as seeking to advance an outside agenda or steer revenue to agricultural retailers. As a profession, crop advisors recommend to farmers practices that will sustain crop yields while reducing expenses and safeguarding farm natural capital, and cover crops fall into this purview. The same structural forces that catalyzed the expansion of private crop consulting may thus also be indirectly contributing to increased use of cover crops, at least among growers of specialty crops.

There is another way of interpreting regression results for crop consultants, however. Namely, it may be that farmers already committed to cover cropping are simply also more likely to hire crop consultants, perhaps to consult on cover crops but also for other reasons. Data collected for this study do not permit examination of the direction of causality between cover cropping and working with crop advisors. Eanes et al. (2017) note that "given their relatively new role in agriculture, literature on [crop advisor]-farmer relationships is relatively sparse compared to other social components of agricultural systems." Further research is needed to more fully explore the role that crop consultants and other private sector actors are playing in the cover crop adoption dynamic. Lessons learned from the specialty crop sector might ultimately be extended to the row crops sector, especially in the Midwest, where cover crop adoption is far below the proportion needed to address soil and water degradation issues (Kladivko et al. 2014).

Finally, farms' historical cropping systems can also be considered part of the underlying context for farmers' decisions. Perennial orchards, in particular, are the result of years of investment and care. If orchard growers have markedly stronger concerns about whether cover crops might negatively impact cash crops, then reliance on fruit crops represents an additional structural factor for cover crop advocacy to consider.

The importance of structural factors to explanations of cover cropping is of more than academic interest. If the market for organic food and engagement with crop consultants are important to cover crop decisions on specialty crop farms, then this has implications for where cover crop advocacy in the future can most productively focus. There is ample reason for cooperative extension and conservationist NGOs to persist in communicating the risks of climate change and extreme weather to farmers (Han et al. 2021). Appeals to farmers' identities and normative goals will likely also continue to be part of a strong case for cover crops. But the results of this study, in the context of the overall note offered by Prokopy et al. (2019), suggest that cover crop advocates cannot at the same time overlook the importance of trying to shape or take advantage of larger structural factors. This may mean devoting new energy to partnerships with independent crop advisors. It may mean emphasizing the ability of farms that adopt conservation practices to connect with new groups of consumers. It may even mean intentionally working to enhance economic incentives for cover crop use and to boost broader social awareness of the environmental benefits of cover crops. Specialty crop farmers have considerable agency in making farming decisions. But changes to the social context within which farmers exercise agency may have the biggest impact on whether and how fast the number of farmers using cover crops continues to grow.

Supplemental Material

The supplementary material for this article is available at https://doi.org/10.7910/DVN/06EDUI.

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