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Characterizing Crop Diversification in the U.S. Specialty Crop Industry

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Abstract

Previous research on-farm diversification has defined diversified farms as those growing four or more crops, yet recent studies have reported specialty crop farmers tend to grow 20 crops. This study brings a characterization of crop diversification for the specialty crop industry and investigates the factors influencing growers to diversify their crop mix. Using an ordered logit regression, we model how farmer demographics, farm characteristics, and attitudes influence farmer's decision to diversify. The results indicate that access to markets, value-added technologies, and organic practices foster crop diversification, while lack of access to labor, farmer's satisfaction, and contract agreements hinder crop diversification.

Keywords: crop diversification, fruit and vegetable, ordered logit, specialty crop

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Introduction

Pushed by improvements in production technologies as well as growth in domestic demand, the contribution of the specialty crop industry in the U.S. economy is expected to increase in the upcoming years (Lucier et al., 2006). To illustrate, the market value of fruits and vegetables increased by 134% and 77%, respectively, in the 1995–2016 period (Minor and Bond, 2017). According to the 2017 Census of Agriculture, specialty crop sales, including nursery and floriculture production, reached more than $60 billion in 2017, representing a 29% increase in the last decade (USDA-NASS, 2007; USDA-NASS, 2017). The 2017 census reported the existence of more than 161,000 operations growing vegetables, citrus, and non-citrus crops, harvesting nearly 7.5 million acres. Data from the 2019 Census of Horticultural Specialties showed that over two-thirds of specialty crop sales go through wholesale channels, while the rest go to local (e.g., farmers' markets) and intermediate markets (e.g., restaurants) (USDA-NASS, 2019).

On the consumption side, the U.S. Bureau of Labor Statistics (2020) reported that fruit and vegetables accounted for almost 19% of home expenditures. While the 2015–2020 Dietary Guidelines for Americans recommends eating at least 2 cups of fruits and 2.5 cups of vegetables per day (USDHHS, 2020), the average consumption of fruit and vegetables is below recommended guidelines. Yet, Glick-Bauer, and Wechsler (2016) reported that most Americans over the age of 4 consume only 1 cup of fruit per day. To address the consumption gap, policymakers and local and federal governments have implemented actions and initiatives to promote fruit and vegetables intake. For example, the U.S. Department of Agriculture (USDA), through their Supplemental Nutrition and Assistance Program (SNAP), supports the food budget of needy families to purchase nutritious foods, including fruits and vegetables (Rosenbaum, 2013). The (USDA-FNS, 2015) reported that SNAP recipients tend to have a direct impact on consumers and farming communities.

The increasing consumer demand for specialty crops presents economic opportunities for farmers (USDA-ERS, 2019; Torres, 2020). However, farmers face a myriad of decisions regarding which crop to grow and what markets to sell into in order to secure profitability. To help address these challenges, the USDA Sustainable Agriculture Research and Education (SARE) program has funded more than 7,468 research and education initiatives in the past three decades. This program has provided $311 million to support farm diversification, access to profitable markets, and overall long-term sustainability. Similarly, the National Sustainable Agriculture Coalition provides small loans (up to $50,000) to diversified farmers serving local markets to help them cover annual operating expenses. The Whole-Farm Revenue Protection (WFRP) supports farmers to insure all of their crops under one policy to assist with risk management strategies of diversified operations.

On-farm diversification is defined as the increase in the number of enterprises on a farm (Barbieri, Mahoney, and Butler, 2008). For example, farmers can diversify their operations by increasing the number of crops, adding value to a crop (e.g., making jams), providing services to other farmers, or accessing new markets (e.g., forward contracting with processors). Major benefits of on-farm diversification include spreading risk through more enterprises, better utilizing resources, improving cash flow, and increasing agronomic and financial resilience to changes to, ultimately, assure profitability (McNamara and Weiss, 2005). While there are many economic and environmental benefits to on-farm diversification, few studies have investigated what drives specialty crop farmers to diversify their crop mix. For an industry in which operations typically grow more than 20 crops (Torres et al., 2016), defining diversified farms as those growing four or more crops does not accurately describe the diversity in the specialty crop sector (MacDonald, Korb, and Hoppe, 2013). The lack of an accurate characterization of crop diversification can have opposing effects in specialty crop operations when compared to row crop farms. Thus, a precise categorization for specialty crop operations can help policy makers and researchers to better understand the factors driving crop diversification across different degrees of farm diversification.

Recently, Lancaster and Torres (2019) provided a framework to capture the degree of crop diversification in the specialty crop industry. Using a quantile regression, their paper categorized specialty crop farms as highly, moderately, and low diversified, as well as specialized farms. Their study proposed that highly diversified operations are those growing 29 crops or more, moderately diversified operations grow between 16 and 28 crops, low diversified grow between 5 and 15 crops, and specialized operations grow less than 5 crops. To compare specialty crops and row crop agriculture, a diversified row crop operation (4 crops) grows the same number of crops as a specialized specialty crop farm.

Following Lancaster and Torres (2019), this study characterized specialty crop farmers at various degrees of diversification. A secondary goal of this study was to investigate the drivers and challenges to diversify. Specifically, this study explored how farm characteristics, farmer's demographics, and attitudinal factors influence their decision to diversify (or not) their crop mix. This information allows us to determine the main factors driving or deterring specialty crop farmers from growing more crops and how these factors influenced operations at different degrees of diversification. Findings can shed light on the market access and perceptions of specialty crop farmers at various degrees of diversification. Findings can also help researchers, policymakers, and Extension personnel to tailor incentives and programs to assist specialty crop growers in spreading risk over more crops.

Crop Diversification

The phrase, "don't put your all eggs in one basket," can be used to capture a farmer's intention of branching out their operation and diversifying income streams. The farmer's decision to diversify income streams is likely a response to market changes (Morris, Henley, and Dowell, 2017) and increasing demand for local and fresh nutrient-dense foods (Low et al., 2020). To respond to these opportunities, farmers can diversify their on-farm income stream by growing more crops, investing in adding value to their crops, or accessing new high-value markets (Lancaster and Torres, 2019).

This study focuses on crop diversification as a major on-farm diversification strategy and draws from Kremen, Iles, and Bacon (2012) to define it as the intentional broadening of crops in a specialty crop farm. We propose that crop diversification is the inclusion and/or rotation of multiple crops in a production system. Historically, studies on crop diversification have focused on traditional row crop systems, which defined a diversified operation as one growing four or more crops (Davis et al., 2012; MacDonald, Korbb, and Hoppe, 2013). Yet, studies of specialty crop operations have reported that the average operation grows between 10 to 30 crops (Torres and Marshall, 2017; Torres and Lancaster, 2019), a major difference from row crop operations.

Studies have reported that diversifying crops can help specialty crop farmers achieve financial and environmental resiliency, manage risk, and compete in agriculture markets. For example, changing climatic conditions, availability of new technologies, market access, price volatility, and risk mitigation are examples of factors driving farmers to diversify their crop mix (Pingali and Rosegrant, 1995; Bradshaw, 2004; Barbieri and Mahoney, 2009; Hendrickson, 2015; Liebman and Schulte-Moore, 2015; Fusco, Miglietta, and Porrini, 2018). Several environmental benefits have been reported among farms diversifying their crop mix including the reduction of pesticide use (Roesch-McNally, Arbuckle, and Tyndall, 2018) and resilience to environmental impacts (Davis et al., 2012). To illustrate, extended crop rotations can reduce pest pressure, which in turn can decrease the use and expenses of pesticides (Hunt, Hill, and Liebman, 2017).

Studies have categorized the factors influencing farmers to diversify their operations as external and internal variables. External variables include factors outside of the farmer's control, such as access to markets and weather (Anosike and Coughenour, 1990). Farmers growing a variety of crops can sell and showcase their produce through a variety of market outlets, including direct-to-consumer (e.g., farmers' markets and roadside stands), intermediate (e.g., restaurants and food hubs), and wholesale markets. This is especially true as Lancaster and Torres (2019) reported specialty crop farmers tend to access up to five different market outlets. By increasing their crop mix, farmers can appeal to a wide variety of customers and leverage from the steadily growing U.S. population at times when the demand for specialty crops is rising. As agricultural production systems become larger and more specialized due to benefits from economies of scale, diversification seems to be a major strategy among smaller operations and those aiming to sell at high-value local markets (Lancaster and Torres, 2019).

Roesch-McNally, Arbuckle, and Tyndall (2018) reported that crop diversification is more likely for farmers already investing in diversified enterprises (e.g., livestock production) and those with less access to land. Having other enterprises in the farm helps farmers channel crop production into other value-added activities. Fusco, Miglietta, and Porrini (2018) suggested that farmers contemplate diversification as a risk mitigation strategy. Other factors motivating farmers to diversify their crop mix included the availability of new technologies, land, labor, and input costs, and access to markets (Pingali and Rosegrant, 1995; Barbieri and Mahoney, 2009).

While some researchers argue that farm diversification is mainly driven by external factors, other internal drivers have been cited by recent literature. Among internal factors impacting crop diversification include farmers' abilities, skills, and perceptions. Farmers expecting that crop diversification can increase farm income tend to be more likely to diversify (Barbieri and Mahoney, 2009). Having an entrepreneurial mindset has been correlated with diversifying farming operations (Barrett, Reardon, and Webb, 2001). In addition, farmland, human capital (i.e., family labor), and networks have been reported as factors motivating farmers to diversify on-farm income (McFadden and Gorman, 2016; Suess-Reyes and Fuetsch, 2016). For example, Valliant et al.

(2017) reported that diversifying on-farm enterprises has helped farmers balance the family-business interface.

Although multiple studies have reported on the advantages and benefits of crop diversification to improve the financial and agronomic resilience of agricultural systems, there are multiple barriers deterring farmers from diversifying their crop mix. First, technological advancements to produce drought-resistant crops have motivated farmers to become larger and specialize in fewer crops (Lin, 2011). In addition, Lin (2011) reported that fewer economic policies and incentives exist for diversified specialty crop systems as compared to row crop operations. To illustrate, Boody et al. (2009) reported that farmers growing row crops (i.e., corn, wheat, soybeans, cotton, and rice) received 89% of the $91.2 billion dedicated to boost income of row crop and livestock farmers from 1995 through 2002.

Drawing from Lancaster and Torres (2019), this study categorized specialty crop operations as highly diversified, moderately diversified, low diversified, and specialized. We investigated the drivers and barriers to crop diversification in the specialty crop industry. We also assessed the significant characteristics of specialty crop operations at different degrees of diversification. Factors influencing crop diversification include farm characteristics, the farmer's demographics, and perceptions. With the ongoing consolidation in the agriculture sector, increasing demand for specialty crops, and an increasingly competitive business landscape, exploring the diversification levels of specialty crop farms is critical for policymakers designing incentives and programs, as well as for research and outreach efforts looking to diversify agricultural systems.

Materials and Methods

Data for this study came from a 2019 web-based survey of specialty crop growers who were part of email lists of grower associations and the Food Industry Market database. The databases provided us with 3,487 email addresses of growers located in 32 states.[1] The compiled list of growers was screened to eliminate duplicate entries and operations. These databases facilitated the access of a wide variety of growers selling in direct-to-consumer (DTC) market channels, intermediate markets, and wholesale outlets. DTC markets are those where the farmer sells directly to consumers, such as farmers' markets (Torres et al., 2016), whereas intermediate markets are those where the farmer sells to local restaurants or independent stores. Lastly, wholesale outlets are those where the farmer sells to processors, distributors, and wholesalers (Woods et al., 2013).

To increase participation rate, we included an incentive of a $10 gift card to the first thousand farmers who completed the survey. Dillman, Smyth, and Christian (2014) reported that including token incentives is likely to increase online survey participation. We sent three email reminders with intervals of two weeks between March and April 2019. A total of 696 farmers growing fruits, vegetables, herbs, and horticulture crops completed the survey, for a response rate of 20%. The

[1] States included Alabama, Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Montana, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Oregon, Rhode Island, Tennessee, Virginia, West Virginia, Wisconsin, and Wyoming.

questionnaire included questions related to the farmer's demographics (i.e., educational attainment, gender, farming experience), farm characteristics (i.e., crops, markets, and growing technologies), and the farmer's beliefs and perceptions toward their farm system. The questionnaire was approved by the corresponding Institutional Review Board for compliance with ethical standards for human subjects.

The sample of this study included 570 operations growing fruits, vegetables, and culinary herbs. For farmers who did not respond, their number of crops grown in 2018 were excluded from the study. A sample of specialty crop farmers exclusively responded that their crop mix provided clear-cut differences between farmer categories. Operations in our sample grew between 1 and 60 crops, with an average of 14 crops and a median of 7 crops. Figure 1 illustrates the distribution of number of crops grown by participants in our sample.

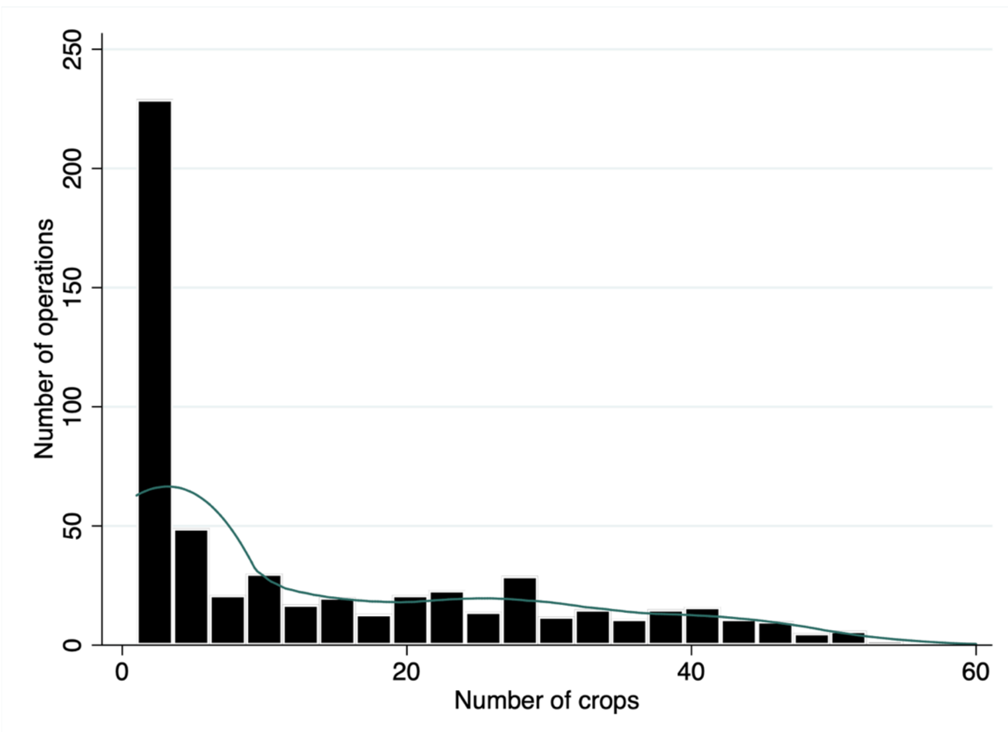

Figure 1. Frequency (bars) and Kernel Density (line) Distribution of the Number of Crops

Drawing from Lancaster and Torres (2019), operations were categorized based on the number of crops as specialized (1 to 4 crops), low (5 to 15 crops), moderately (16 to 28 crops), and highly diversified (29 crops or more). Thus, this study proposed that crop diversification is an ordered process, in which increasing the number of crops increases the level of diversification. Most of the growers in our sample fell into the specialized category (44%; N = 249), followed by highly diversified (20%; N = 114), low diversified (19%; N = 111), and moderately diversified (17%; N = 96) (Figure 2). Multiple comparisons were made among means in the analysis of variance (ANOVA) models using Tukey's honestly significant difference method at the 10% significance level. Diversification level (i.e., specialized, low, moderately, and highly diversified) was considered as a treatment effect for means comparisons across columns. Chi-square tests were used to measure the relationship between means and yielded similar outcomes than ANOVA and Tukey's test. All analyses were conducted using Stata (release 16; StataCorp, College Station, TX).

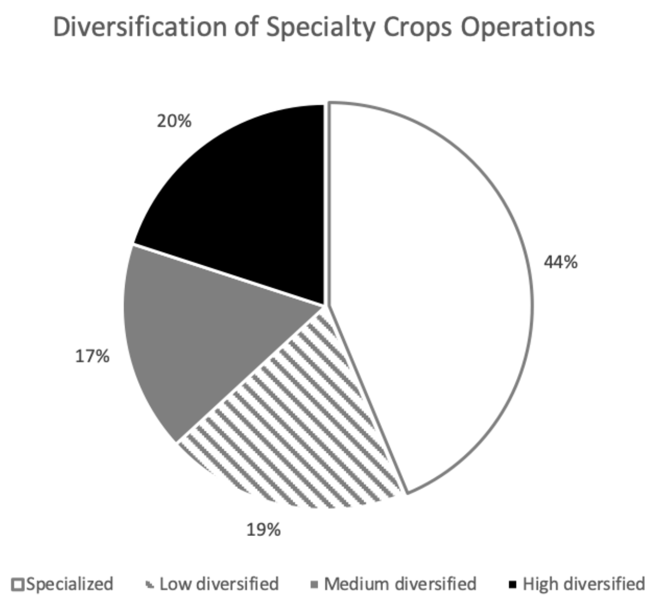

Figure 2. Proportion of Diversification Quantiles among Specialty Crop Operations

Using an ordered logit regression, we investigated the likelihood that farm characteristics, farmer's demographics, and perceptions influenced crop diversification. The ordered logit is an appropriate framework to model ordinal survey responses where the observed dependent variable (i.e., number of crops) has an ordinal scale (Greene, 2003). For instance, as the number of crops increases, diversification increases, following a naturally ordered scale. Thus, we assumed that diversification has a natural ordering (from specialized to low, moderately, and highly diversified).

The ordered logit is based on the random utility theory, which assumes that farmers choose the number of crops that would give them the highest level of utility (profit). The ordered logit is based on a latent continuous variable Y^*, which is a linear combination of vector characteristics (X) describing the individual, a set of parameter vectors (β), and an error term ε assumed to have a standard logistic distribution. Letting i = 1, 2, …, j index of clusters, and for the case of four diversification levels (i.e., $y_i \in [1,2,3,4]$):

$$Y_i^* = X_i\beta + \varepsilon_i \tag{1}$$

While the unobserved latent variable is Y_i^*, we were able to observe y_i, which is the observed ordinal variable:

$$Y_i = 1 \ if \ y_i^* \leq \kappa_1$$

$$Y_i = 2 \ if \ \kappa_1 < y_i^* \leq \kappa_2$$

$$Y_i = J \ if \ y_i^* > \kappa_{J-1}$$

Consequently:

$$\Pr[y_i = j] = \Pr\ [y^* \text{ is in the } j\text{th range}]$$

Hence, the probability of observing a level of farm diversification can be written as:

$$\Pr[y_i = j] = F\left[\kappa_J - \beta' X_i\right] - F\left[\kappa_{J-1} - \beta' X_i\right] \tag{2}$$

where F(.) = exp(.)/[1+exp(.)], implying that

$$\Pr[y_i = j] = \frac{1}{1 + e^{-\kappa_J + \beta' X_i}} - \frac{1}{1 + e^{-\kappa_{J-1} + \beta' X_i}}$$

which were used to derive the maximum likelihood estimates of κ and β.

Table 1 illustrates the set of covariates X_i, in Equation 1, which includes farm characteristics, farmer's demographics, and perceptions and attitudes toward their agricultural system. A correlation test performed to the set of covariates indicated the lack of correlation among independent variables, which suggests a lack of multicollinearity among the covariates in X_i. Farm characteristics include selling only in DTC market channels, number of markets, percentage of production under organic practices, use of growing technologies (e.g., hoop houses, greenhouses, irrigation, etc.), use of cooling system, use of traceability system, if farmer has insurance, use of value-added technologies (cutting, washing, or drying produce), percentage of production sold under contract in 2018, the legal structure of the farm, number of employees, farm location, and revenues size. Farmer's characteristics include educational attainment, gender, number of generations running the farm business, if farmer has an off-farm source of income, and farming experience. Lastly, farmers' perceptions include their satisfaction with the farming system, perceptions of success, and sources of useful information.

Following the U.S. Census Bureau, farmers were grouped in four geographic regions: Northeast, Midwest, West, and South. The Northeast region includes operations located in Maine, Massachusetts, and New York. The Midwest region includes farms located in Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin. The West region includes operations located in Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, and Wyoming. Lastly, the South region includes farms located in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Tennessee, Virginia, and West Virginia. We followed Torres et al. (2016) to base small sales cutoff for farm size category. Small operations are those reporting sales of less than $50,000 in 2018.

Results and Discussion

Summary Statistics

Table 1 provides the summary statistics for the sample of farmers used in this study. Forty-five percent of specialty crop farmers sold their produce solely through DTC market channels. The average number of market outlets accessed by farmers was more than two markets. The average percentage of production sold under contracts in 2018 was 25%. On average, farmers in our sample reported a third of their production was produced using organic practices. Most farmers in our sample used growing technologies (91%), almost two-thirds used cooling systems, and less than a quarter of them had a traceability system (e.g., lot numbers, labeling guns, bar codes, and paper or electronic markets). About 80% of growers in our sample had a form of insurance, including crop, equipment, income, property, worker compensation, or liability insurance. The average operation farmed 271 acres and employed 18 workers, including family, full-time, and part-time employees.

Most farmers in our sample had at least some college education (59%), and about a third of respondents were women or farmed part-time. The average farm had been operating for two generations. Most growers (60%) reported being satisfied with their current farming system, but less than a third perceived themselves as more successful than the previous year. It is interesting to note that 49% of farmers reported Extension services as a useful source of information, whereas only 23% of farmers reported other farmers as useful sources of information.

Table 2 provides the results from the ANOVA analysis, which includes the mean differences for all the variables used in the model by level of crop diversification. Selling directly to consumers and selling through a high number of market channels were less common for specialized operations ($P < 0.1$). It is likely that focusing on a few crops and selling them through wholesale markets are helpful strategies for specialized operations to remain profitable. This is especially true as our findings suggest more specialized operations appeared to be reaching wholesale markets through contracts ($P < 0.1$). Results suggest that crop diversification is correlated with increasing market access, which are two common strategies adopted by small- and medium-sized operations (Pingali and Rosegrant, 1995).

The proportion of women, young, and beginning farmers was higher among moderately and highly diversified farms than their counterparts ($P < 0.1$). Our findings are consistent with researchers who have reported women farmers tend to favor diversified production systems (Trauger et al., 2010; Sachs et al., 2016). It seems that having a diversified crop mix enables female farmers to increase farm sustainability, access to local markets, and promote social and environmental goals for their community.

Table 1. Categories and Descriptions of the Variables Used to Investigate the Characteristics of Diversified Operations among 570 Specialty Crop Farmers of 32 States in the Uni'ted States

Variable	Obs.	Mean	Std. Dev.	Description
Farm characteristics				
Number of crops	570	14.09	14.82	Number of crops including fruits, herbs, and vegetables
Only DTC[Z]	570	0.45	0.50	1 = if farmer only uses direct to consumer market channels (at farm, farmers markets, CSA, internet, independent grocery stores, and restaurants)
Number of markets	570	2.32	1.45	number of market channels including DTC, wholesale, processors, schools, wineries, food hubs, and miscellaneous
Percent organic	570	37.76	46.59	Percentage of current production that falls under organic (certified and noncertified) practices
Growing technologies[Z]	570	0.91	0.29	1 = if farmer uses growing technologies such as artificial lighting, hydroponics, plasticulture, irrigation, hoop houses, greenhouses, etc.
Cooling system[Z]	570	0.63	0.48	1 = if farmer uses cooling system such as cold storage, forced air cooling, hydrocooling, ice cooling, modified atmosphere packaging, room cooling, vacuum cooling.
Traceability system[Z]	570	0.25	0.43	1 = if farmer uses a traceability system such as lot numbers, labeling guns, bar codes, and paper or electronic markets
Insurance[Z]	570	0.79	0.40	1 = if farmer paid for insurance in 2018, including crop, equipment, income, property, worker compensation, and liability insurance
Value-added[Z]	534	0.52	0.50	1 = if farmer used value-added technologies in 2018 including washing, cutting, or drying
Percent contracts	570	0.25	0.43	Percentage of production sold under contracts in 2018
Total land	570	270.69	843.61	Number of acres farmer rents or own
Sole proprietorship[Z]	570	0.40	0.49	1 = if farm's business structure is sole proprietorship
Labor	570	18.19	46.30	number of people working on the farm including family members and respondent, permanent, and temporary employees
Small[Z]	570	0.09	0.29	1 = if annual gross sales lower than $50,000
Northeast	507	0.05	0.21	1 = if farm is located in Maine, Massachusetts, New York, and Maine
Midwest	507	0.52	0.50	1 = if farm is located in Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin

Table 1 (continued).

Variable	Obs.	Mean	Std. Dev.	Description
West	507	0.24	0.43	1 = if farm is located in Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, and Wyoming
South	507	0.19	0.39	1 = if farm is located in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Tennessee, Virginia, and West Virginia. Reference group
Farmer characteristics				
College[Z]	570	0.59	0.49	1 = individual has college education or postgraduate work
Female[Z]	570	0.29	0.46	1 = if farmer is female
Generations	505	1.93	1.17	Number of generations the family has been running the farm business
Part-time[Z]	570	0.31	0.46	1 = if farmer works in the farm part-time
Years farming	513	24.33	15.59	number of years farming
Farmer perceptions				
Satisfied[Z]	570	0.59	0.49	1 = if farmer is satisfied with his/her present farming system
Successful[Z]	570	0.31	0.46	1 = if farmer perceived being more successful than previous year
Info farmer[Z]	570	0.23	0.42	1 = if farmer perceives other farmers provide useful information
Info Extension[Z]	570	0.49	0.50	1 = if farmer perceives university extension provides useful information

[z]The mean is the percentage of respondents with that attribute.

One might speculate that young and beginning farmers tend to operate diversified operations due to a lower risk aversion. Another explanation may be that these young and beginning farmers start diversified and become more specialized as they expand their operation and market access.

Lastly, Table 2 illustrates how specialty crop farmers' perceptions and attitudes differed depending on their diversification degree. For example, a higher percentage of farmers operating diversified farms (low, moderately, and highly) perceived themselves as more successful than specialized operations ($P < 0.1$). It is likely that diversified farmers associate success with building farming ecosystems that are highly diversified and contribute to their social and environmental motives. Similarly, the usefulness of information from Extension services was more common among diversified (low, moderately, and highly) than specialized farmers ($P < 0.1$).

Regression Results

Table 3 displays the coefficients and marginal effects of the likelihood of becoming highly diversified. This study used robust coefficients to provide conservative estimates and address potential heteroskedasticity. The main finding from Table 3 shows that the number of markets and use of growing and value-added technologies are significant drivers of crop diversification among specialty crop operations. Other major factors influencing crop diversification are demographics, farm characteristics, perceptions, and sources of information.

Findings from Table 3 show that using growing and value-added technologies have the highest impact on crop diversification. For instance, farmers using hoop houses, greenhouses, hydroponics, irrigation, or plasticulture were 13% more likely to highly diversify their crop mix ($P < 0.1$). Similarly, farmers washing, cutting, and/or drying their produce were 12% more likely to diversify ($P < 0.01$). Economies of scale and economies of scope can be used to explain the effect of technology adoption on crop diversification. On the one hand, by adopting growing technologies farmers may rely on economies of scale to increase outputs while decreasing the cost per crop unit (Robinson and Barry, 1987). To illustrate, hoop houses are common agricultural technologies helping specialty crop farmers control and extend the growing season of a specialty crop (Lamont, 2005). With longer growing seasons, farmers using hoop houses can add new crops to their agricultural system, increase yield, and potentially boost revenue. On the other hand, farmers may rely on economies of scope by differentiating their diverse crop mix through the adoption of value-added technologies (Womach, 2005). For example, converting a specialty crop into jams, sauces, and dried produce can help them access markets, increase off-season income, and receive price premiums for their products.

Access to markets is an important driver of farm diversification. Selling in DTC markets and increasing the number of market outlets increase the likelihood that a farm diversifies their crop mix by 5% and 4%, respectively ($P < 0.01$). The demand for local foods and the farm-to-fork movement have created important market opportunities for growers selling through local markets. By selling directly to consumers, growers have access to direct feedback to adjust their crop mix. For example, farmers selling at farmers' markets may be motivated to diversify their crop mix as a way to differentiate from other vendors and improve the display of their stand. Alternatively, selling through contracts decreases the likelihood of crop diversification by 5% ($P < 0.05$). Following Wang, Wang, and Delgado (2014), contract farming may motivate farmers to focus on growing fewer crops as a way to minimize production costs and maximize output.

Female farmers are 4% more likely to increase crop diversification ($P < 0.1$). Women may be more likely to diversify their crop mix as a way to enhance biodiversity of their farming systems. Amekawa et al. (2010) proposed that women's motives to diversify are twofold: increasing income and improving agrobiodiversity. By diversifying the crop mix, women may be able to spread out risk among multiple crops (Amekawa et al., 2010), expand new sources of income, and exploit niche markets (Warren-Smith and Jackson, 2004). By improving agrobiodiversity, female farmers may be looking to promote ecosystem diversity (Warren-Smith and Jackson, 2004) while balancing family-farm demands (Anthopoulou, 2010). Warren (2002) proposed that the participation of women in diverse and innovative farm businesses tends to promote their empowerment, especially in rural areas.

Other factors increasing crop diversification include the use of organic practices, the legal structure of the farm, and useful sources of information. Operations using organic practices are more likely to diversify their crop mix ($P < 0.01$), which may be due to the use of intercropping and crop rotations practices commonly adopted by organic farmers (Ponisio et al., 2015). By diversifying crop production in organic systems, farmers aim to increase ecological interaction that helps improve yield and profitability of their operations. Operations structured as sole proprietorships were 4% more likely to increase crop diversification ($P < 0.05$). The flexibility and control of a sole proprietorship may encourage growers to engage in diversification and differentiation strategies that increase market access and profitability. Our findings show that access to information is a major determinant of increasing crop diversification. Farmers accessing useful information from Extension services are 4% more likely to diversify their crop mix ($P < 0.05$). Other researchers have reported having access to Extension information increases the adoption of farming practices and technologies (Oladele, 2005; Mussema et al., 2015; Mwololo et al., 2019).

Factors decreasing the likelihood of crop diversification include labor ($P < 0.01$), farming part-time ($P < 0.01$), and farmers' satisfaction with the current farming system ($P < 0.1$). The fact that increasing the number of employees increases the likelihood of becoming more specialized is unexpected. One explanation may be that larger operations (in terms of land) are more likely to need more labor, especially temporary and migrant workers. Another explanation may be that due to labor shortages, highly diversified operations may be able to lower labor costs by using mechanization and labor-saving technologies (Lin, 2011). This is especially true for operations growing tree fruits, grapes, and berries. We expect that part-time farmers are likely to have other sources of off-farm income (Evans and Llbery, 1993) and less time to engage in diversification strategies. Lastly, farmers satisfied with their production system are less likely to diversify their enterprise. This could be related to the belief that specialization can help achieve higher technical efficiency (Mugera and Langemeier, 2011); therefore, it is likely that farmers satisfied with their production system are not motivated to diversify their enterprise and prefer to opt for the best cost-effective method for their business model.

Table 2. Comparison of Characteristics of Specialty Crop Growers Categorized by Level of Diversification (full sample, $N = 570$; specialized, $N = 249$; low diversified, $N = 111$; moderately diversified, $N = 96$; highly diversified, $N = 114$)

	Specialized[y] **1 to 4 crops**			**Low diversified 5 to 15 crops**			**Moderately diversified 16 to 28 crops**			**High diversified 29 crops and more**		
Farm characteristics												
Only DTC[Z]	0.35	0.48	C	0.54	0.50	B	0.61	0.49	A	0.46	0.50	BC
Number of markets	1.83	1.27	C	2.32	1.60	B	2.70	1.30	AB	3.09	1.39	A
Percent organic	18.38	37.28	C	27.51	42.66	C	50.07	47.56	B	79.72	37.00	A
Growing technologies[Z]	0.88	0.33		0.88	0.32		0.98	0.14		0.92	0.27	
Cooling system[Z]	0.51	0.50	B	0.63	0.48	B	0.79	0.41	A	0.76	0.43	A
Traceability system[Z]	0.29	0.46	A	0.19	0.39	AB	0.17	0.37	B	0.27	0.45	A
Insurance[Z]	0.76	0.43	B	0.77	0.43	B	0.90	0.31	A	0.82	0.38	AB
Value-added[Z]	0.29	0.45	C	0.50	0.50	B	0.78	0.42	A	0.78	0.42	A
Percent contracts	0.35	0.48	A	0.16	0.37	B	0.15	0.35	B	0.20	0.40	B
Total land	367.17	1011.07	A	295.38	1043.05	AB	169.72	386.48	AB	120.97	320.89	B
Sole proprietorship[Z]	0.33	0.47	B	0.42	0.50	AB	0.53	0.50	A	0.41	0.49	AB
Labor	25.99	61.92	A	15.73	29.93	AB	11.99	36.52	B	8.78	11.16	B
Small[Z]	0.09	0.29		0.14	0.35		0.05	0.22		0.08	0.27	
Northeast	0.03	0.18		0.07	0.26		0.05	0.23		0.04	0.20	
Midwest	0.51	0.50		0.52	0.50		0.58	0.50		0.50	0.50	
West	0.25	0.43		0.21	0.41		0.20	0.41		0.30	0.46	
Northeast	0.03	0.18		0.07	0.26		0.05	0.23		0.04	0.20	
Farmer characteristics												
College[Z]	0.56	0.50		0.57	0.50		0.67	0.47		0.61	0.49	
Female[Z]	0.21	0.41	B	0.23	0.43	B	0.41	0.49	A	0.43	0.50	A
Generations	2.06	1.19	A	2.16	1.23	A	1.79	1.17	AB	1.57	0.99	B
Part-time[Z]	0.36	0.48	A	0.36	0.48	A	0.29	0.46	AB	0.17	0.37	B
Years farming	25.55	15.24	A	25.91	17.76	AB	23.46	15.79	AB	21.03	13.40	B

Table 2 (continued).

	Specialized[y] 1 to 4 crops			Low diversified 5 to 15 crops			Moderately diversified 16 to 28 crops			High diversified 29 crops and more		
Farmer perceptions												
Satisfied[Z]	0.62	0.49		0.55	0.50		0.59	0.49		0.56	0.50	
Successful[Z]	0.27	0.44	B	0.31	0.46	AB	0.41	0.49	A	0.33	0.47	AB
Info farmer[Z]	0.25	0.43		0.26	0.44		0.21	0.41		0.18	0.38	
Info Extension[Z]	0.45	0.50	B	0.49	0.50	AB	0.59	0.49	A	0.49	0.50	AB
N. Obs.		249			111			96			114	

[z]The mean is the percentage of respondents with that attribute.

[y]Any two means within a row show the significant difference between the diversification categories at $P < 0.1$ using Tukey's significant different test.

Table 3. Coefficient and Marginal Effects Results from Ordered Logit for Diversification Categories of Specialty Crop Operations

	Coefficient	**Std. Err.**		**Marginal Effect**	**Std. Err.**	
Only DTC	0.55	0.22	***	5.27	2.14	***
Number of markets	0.45	0.09	***	4.28	0.91	***
Percent organic	0.02	0.00	***	0.15	0.03	***
Growing technologies	1.40	0.77	*	13.28	7.38	*
Cooling system	0.33	0.23		3.10	2.21	
Traceability system	-0.47	0.25	*	-4.45	2.37	*
Insurance	0.53	0.34		5.02	3.22	
Value-added	1.23	0.20	***	11.72	2.12	***
Percent contracts	-0.50	0.24	**	-4.79	2.34	**`
Total land	-0.01	0.00		-0.01	0.00	
Sole proprietorship	0.42	0.20	**	4.00	1.95	**
Labor	-0.01	0.01	***	-0.09	0.03	***
Small	0.21	0.35		1.98	3.36	
Northeast	0.12	0.50		1.11	4.74	
Midwest	0.35	0.26		3.32	2.51	
West	0.26	0.30		2.47	2.87	
College	0.29	0.20		2.75	1.93	
Female	0.38	0.20	*	3.59	1.95	*
Generations	0.14	0.10		1.31	0.93	
Part-time	-0.63	0.22	***	-5.98	2.16	***
Years farming	0.01	0.01		0.05	0.07	
Satisfied	-0.36	0.20	*	-3.42	1.89	*
Successful	0.08	0.20		0.74	1.91	
Info farmer	-0.19	0.22		-1.84	2.09	
Info Extension	0.41	0.19	**	3.89	1.82	**
Number of observations = 487						
Prob > Chi^2 = 0.00						
Pseudo R^2 = 0.22						

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Marginal effects are expressed in percent points and provide the effect of each explanatory variable on the likelihood of increasing crop diversification.

Conclusions

Diverse agricultural systems have long been the goal of many federal and local programs aiming to support the economic, environmental, and social sustainability of U.S. agriculture. Yet, efforts to categorize farm-level diversification for specialty crop farms are still at their early stage. Using a framework proposed by Lancaster and Torres (2019), this study provides a baseline of crop diversification in the current specialty crop industry. The main contribution of this article is the empirical evidence of the key drivers and barriers of crop diversification among specialty crop growers.

Access to markets, use of growing and value-added technologies, selling in local markets, and using Extension services information are major drivers of crop diversification in the specialty crop industry. Other drivers of crop diversification include being female, having a sole proprietorship legal structure, and using organic practices. Alternatively, farming part time, increasing the percentage of sales via contracts, using traceability systems, and being satisfied with the current farming system were identified as major deterrents to crop diversification. These findings can help policy makers, researchers, and Extension personnel aiming to support farmers by tailoring incentives that assist farm diversification. Furthermore, a number of policy recommendations ascend as a result of the findings from our empirical analysis.

First, findings show that programs and education materials from Extension services are positively influencing farmers to increase cropping system diversity. One explanation may be the fact that Extension programs and information are interdisciplinary in nature. It seems that the integration of research-based Extension programming that crosses disciplines effectively motivates farmers to allocate productive resources to diversify their crop portfolio, which in turn may diversify U.S. agricultural systems. Our findings suggest that researchers and Extension personnel should develop research-based training and education programs that address a combination of production, handling, processing, and marketing needs of farmers wanting to diversify. Information related to cost-efficient technologies for value-added practices and organic agriculture seem to be especially important for specialty crop operations aiming to diversify their crop portfolio.

Second, initiatives that improve access to markets may benefit farmers in diversifying their crop mix. It seems the importance of linking markets to buyers and end-consumers goes beyond increasing diversified farming systems. Understanding market grade standards, purchasing and delivery agreements, packaging, and cleaning requirements are critical to support farmers having a profitable portfolio of crops with appropriate agricultural, handling, and storage practices. Initiatives supporting crop diversification are likely to improve the sustainability of local food systems by strengthening key linkages among farmers, local entrepreneurs, and consumers. Benefits will also accrue to rural and urban communities as access to fresh locally produced fruits, vegetables, and horticulture crops will increase and producers will continue farming.

Further research should investigate how diversified farmers tend to behave over a period of time. Farmers are likely to change or move out of production systems, markets, and technologies; thus, future investigation should focus on drivers and barriers that lead farmers to keep their systems diversified. The economic literature suggests that on-farm diversification provides economic benefits, yet it is unknown the degree of economic benefit perceived from different levels of diversification. Future research should be conducted to measure how the diversification groups impact farmers' economic sustainability. Although the results of this study provide insights into the drivers and barriers to crop diversification, there are several limitations that should be acknowledged. The analysis relies upon farmers accurately reporting their production, market, and technological practices. Another possible limitation of this study may be the fact that by using an online survey, which is a convenient data collection technique, this study focused on farmers using internet and may not reflect the general farming population. Thus, further research should use other sampling and data collection techniques to include non-internet users.

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