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The "Sweet Spot" in the Middle: Why Do Mid-Scale Farms Adopt Diversification Practices at Higher Rates?

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In the past few decades, farmers and researchers have firmly established that biologically diversified farming systems improve ecosystem services both on and off the farm, producing economic benefits for farmers and ecological benefits for surrounding landscapes. However, adoption of these practices has been slow, requiring a more nuanced examination of both barriers and opportunities to improve adoption rates. While previous research has demonstrated that both individual and structural factors shape farmers' decisions about whether to adopt diversification practices, this study aims to understand the interaction of these individual and structural factors, and how they relate to farm scale. Based on 20 interviews with organic lettuce growers on the Central Coast of California, as well as 8 interviews with technical assistance providers who work with these growers, we constructed a typology to help elucidate the distinct contexts that shape growers' decisions about diversification practices. This typology, which reflects the structural influence of land rent and supply chains, divides growers into three categories: limited resource, mid-scale diversified, or wholesale. In this economic context, limited resource and wholesale growers both experience significant barriers that constrain the adoption of diversification practices, while some mid-scale diversified growers have found a "sweet spot" for managing agroecosystems that can succeed in both economic and ecological terms. The key enabling factors that allow these farmers to choose diversification, however, are not directly related to their farm size, but have more to do with secure land tenure, adequate access to capital and resources, and buyers who share their values and are willing to pay a premium. By focusing on these key enabling factors with targeted policies, we believe it is possible to encourage diversification practices on farms at a variety of scales within California's Central Coast.

Keywords: sustainable agriculture, agroecology, agricultural policy, diversified farming systems, farm management, land access, supply chains, farming models

INTRODUCTION

In the past few decades, farmers and researchers have firmly established that biologically diversified farming systems improve ecosystem services both on and off the farm, producing economic benefits for farmers and ecological benefits for surrounding landscapes (Tscharntke et al., 2005; Kremen and Miles, 2012; Tamburini et al., 2020). Such biologically diversified farms incorporate numerous types of *planned* biodiversity, including a wide variety of cash and cover crops as well as non-crop plants such as hedgerows or floral strips to support beneficial insects. Many also incorporate *unplanned* biodiversity, by preserving some wild elements or natural areas within the farm, or attracting various species to planned elements (e.g., hedgerows). Such practices nurture biodiversity below ground, helping farmers build soil health, which directly supports crop growth while improving resilience to disease, drought, and floods (Gaudin et al., 2013; Poeplau and Don, 2015; Smith et al., 2018; Weisberger et al., 2019; Archer et al., 2020; Bowles et al., 2020; Wade et al., 2020). At the same time, enhancing biodiversity on the farm promotes aboveground services like pollination and pest control by providing habitat for pollinators, beneficial insects, and other wildlife (Kremen and Miles, 2012; Morandin et al., 2016; Garratt et al., 2017; Dainese et al., 2019). Given the benefits of such practices—which we will refer to throughout the paper as "diversification" practices, though many of them are also frequently referred to as regenerative or soil health practices—one might assume that they would be widespread. Yet U.S. farmers have adopted them at dismally low rates.

To understand this conundrum, researchers have turned to the extensive literature on farmer adoption of conservation practices. Starting with work that observed uneven diffusion of agricultural practices among Iowa farmers (Ryan and Gross, 1943), much of the early agricultural adoption literature focused on individual farmer-level characteristics that explained this unevenness. For example, general awareness and perception of soil erosion and other soil issues, education level, years of experience, and age have all been found to correlate positively with adoption of conservation practices (Gould et al., 1989; Warriner and Moul, 1992; Napier and Camboni, 1993; Traoré et al., 1998).

However, studies have also found negative and non-significant results for each of these same characteristics (Clay et al., 1998; Traoré et al., 1998; Neill and Lee, 2001). Indeed, recent reviews have generally found that there are no universal rules or characteristics that reliably predict adoption of diversification practices (Knowler and Bradshaw, 2007; Prokopy et al., 2008, 2019; Baumgart-Getz et al., 2012; Carlisle, 2016). Rather, it has emerged that farms and farm communities are hugely heterogeneous, and consideration of local specificity is critical. In addition to local specificity, researchers find that structural factors such as government policies, incentive programs, and supply chain requirements strongly impact farmer willingness and ability to adopt diversification practices (Stuart and Gillon, 2013; Reimer et al., 2014; Liu et al., 2018; Prokopy et al., 2019; Baur, 2020). Thus, there is a need to better understand and address the interplay between structural and individual-level factors, and specifically how structural factors differentially impact farms in various locales, and of differing scales and business structures.

We assessed these factors as part of an interdisciplinary study in California's Central Coast, a highly productive agricultural region with high land values, concentrated supply chains, a complex policy environment, and a robust alternative agriculture movement. Environmental impacts from intensive agricultural production in the region include degraded groundwater quality (Rosenstock et al., 2014; Harter, 2015) and reduced natural habitat for the region's biodiversity, which includes a major migratory bird flyway and several federally and/or state-endangered species (Gennet et al., 2013). Understanding why different types of farms do or do not adopt diversification practices, and how this in turn impacts associated biodiversity and environmental outcomes, will provide important information for regionally-specific policy interventions.

METHODS

Study Site

California's Central Coast, often called America's salad bowl, supplies 70% of America's leafy greens and 50% of its broccoli, with agricultural revenues of ∼$7 billion annually (California Department of Food Agriculture., 2014). Rugged ranges of coastal hills cover much of this topographically complex region, while farming concentrates along river valleys. Our study focused on the farming valleys of the Pajaro, San Juan, and Salinas rivers (located in Santa Cruz, San Benito, and Monterey Counties, respectively), at the northern end of the Central Coast (**Figure 1**). We also had one respondent who had recently moved to Santa Clara County.

Agricultural operations range from farms of a few acres located in the smaller, hillier valleys—which typically serve local markets—to farms of many thousands of acres in the flatlands of the main valleys, which supply national and global outlets. Key supply chain actors include farmers, shippers (businesses that aggregate the output of many farmers), wholesale buyers, food processors, and retailers (Calvin et al., 2017). Buyers, retailers, and food processors exercise large influence in the region through their ability to set contractual production standards (e.g., for timing, volume, types of farming practices used, and product quality). Marketing has been concentrated for well over a decade. For example, in 2011, the top eight California shippers controlled ∼80% of the California/Arizona iceberg lettuce volume (Cook, 2011).

Farmers in the Central Coast also operate in a policy-dense environment. A number of California state policies aim to incentivize environmentally beneficial practices—such as soil conservation or carbon capture—and regulate other practices, such as nitrate pollution. The Healthy Soils Program (HSP), effective September 2016, provides incentives for farmers to adopt practices such as cover-cropping and compost additions that may sequester carbon in soils (Clapp and Fuchs, 2009). Funded by proceeds from greenhouse gas emissions cap and trade auctions, HSP has awarded three rounds of competitive

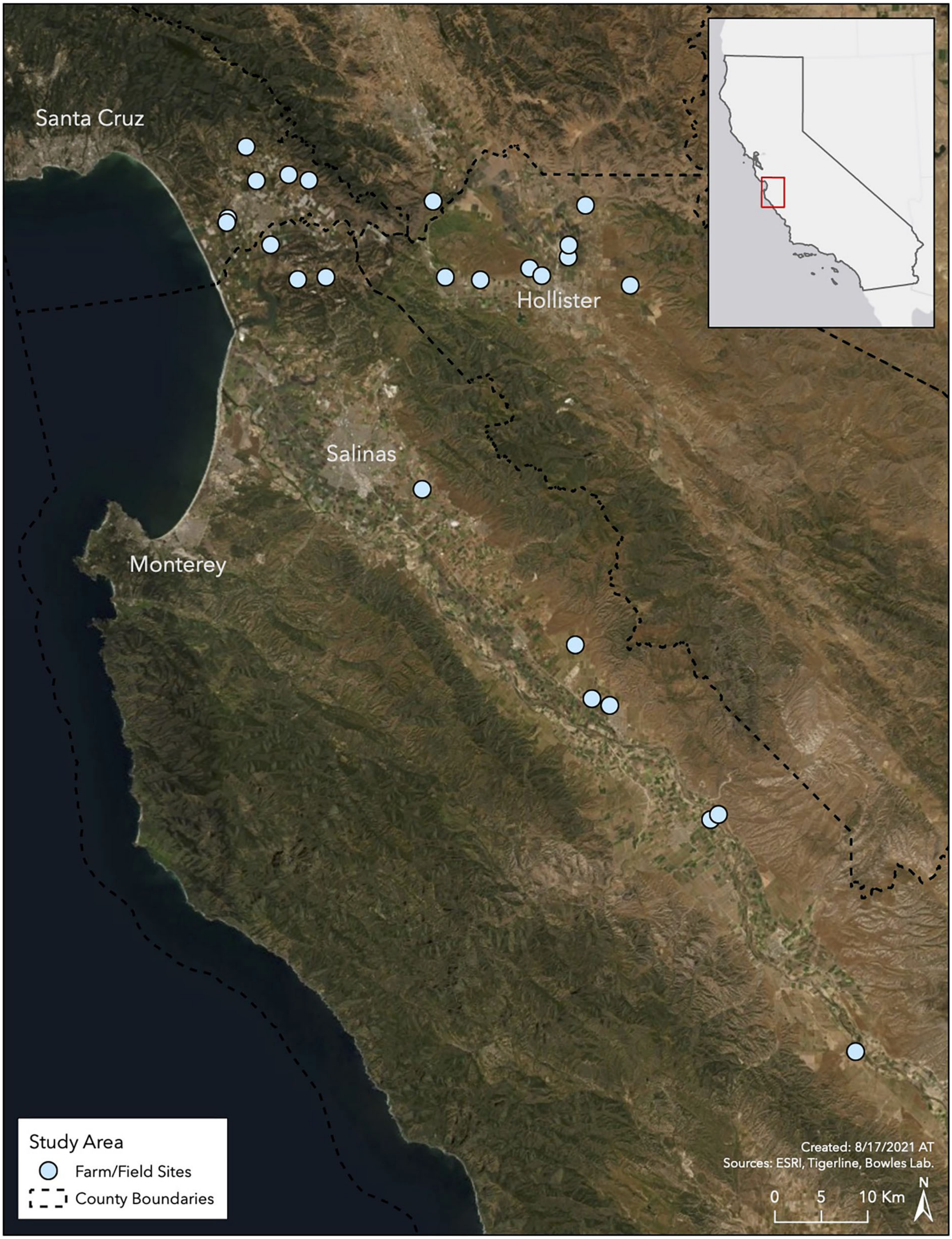

FIGURE 1 | Map of the Central Coast Region. A map of the study region showing the distribution of farm and field sites. Some farms had multiple field locations where ecological surveys were conducted, hence there are more points than number of interviews.

grants to farmers as of 2021 (CDFA—OEFI—Healthy Soils Program., 2021). Meanwhile, the Central Coast Regional Water Quality Control Board imposes a range of water quality-related obligations on farmers, including groundwater monitoring and nitrogen application reporting (Dowd et al., 2008; Drevno, 2018).

Qualitative Interviews

Qualitative data were collected in February 2019 through semi-structured, in-depth interviews with 20 farmers across four counties: Monterey (5 interviews), San Benito (4), Santa Cruz (5), and Santa Clara (1), with 5 farmers spanning multiple of these counties. We limited the study to organic farmers who grow lettuce as their primary cash crop or as part of a diverse portfolio of crops. To identify potential interviewees, we first queried the USDA Organic Integrity Database to identify organic farms listing lettuce as a crop, with 80 results. We consulted with technical assistance providers to identify which of these operations might be willing to participate in the study and were currently growing lettuce. Because this qualitative research was carried out as part of a larger project involving on-farm ecological research, our study design was to select growers from this subset, representing a gradient of both farms and surrounding landscapes that ranged from low levels of biodiversity to relatively high ones. We further chose growers to represent different farm scales, geographical locations within the study region, and cultural backgrounds/first languages. The 20 farmers interviewed for this study account for roughly 25% of organic lettuce producers in this region. In addition to interviewing growers, we also interviewed 8 technical assistance providers who work with organic lettuce farmers in the region, in May 2019. Interviewing these technical assistance providers, who spoke from their knowledge of the sector as a whole, allowed us to corroborate what we learned from grower interviews about factors influencing adoption of diversification practices (such as land values, supply chain requirements, and food safety).

The interview protocols (see **Supplementary Materials**) focused on diversification practices, crop and non-crop diversity, and how these farm-level decisions were shaped by a variety of market and policy factors. We began by asking open-ended questions (e.g., what practices do you currently use to maintain or improve soil health on your farm?), and followed with more specific questions (e.g., could you briefly describe your tillage practices?). Interviews were digitally recorded and transcribed verbatim. Analysis of interview transcripts was conducted in Nvivo 12, using an iterative coding method following an open, axial, and selective coding procedure (Corbin and Strauss, 1990). Through an iterative coding procedure aimed at identifying key factors influencing farmer adoption of diversification practices, data were coded into thematic categories, including “Land Tenure,” “Markets,” and “Food Safety.”

Ecological Surveys

To understand how farming decisions affected unplanned, on-farm biodiversity, we surveyed birds on 23 farms, operated by 14 of the interviewed growers, using 10 min, 50 m fixed-radius point count surveys, repeated three times over consecutive days from May–July of 2019–2020. Point count locations were separated by at least 100 m (Ralph et al., 1995). Thus, the number of point counts per farm varied by farm size. At least half of the survey locations on each farm were centered in lettuce crops; the other half were located within other dominant crop types (e.g., squash, broccoli, strawberry). All surveys were conducted by the same skilled observer, primarily between sunrise and 10:30 am and always in the absence of rain or heavy fog. All individuals seen or heard within the survey radius were identified to species and recorded. Within each 50 m radius point count, we also estimated the percent cover of each crop and then used these data to quantify crop diversity (i.e., Simpson’s index) within each point count radius. We also scored the percent cover of weeds within each crop type ($1 = 0–5\%$; $2 = 5–50\%$; $3 > 50\%$).

Using the farm type classification that emerged from our interview data, we modeled crop diversity and weediness using generalized linear mixed models (GLMMs), followed by Tukey *post-hoc* tests to compare differences between farm types. We included a random effect of farmer identity to account for non-independence among management strategies. Crop diversity was square root transformed to satisfy model normality assumptions and modeled with a Gaussian distribution. Weediness was converted into a binomial variable. A point-count location was considered “weedy” if any crop within the 50 m radius had $>5\%$ weed cover.

We used an N-mixture model (see **Supplementary Methods**) that accounts for unseen species and variation in detection probability to estimate the abundance of each bird species at each site (Royle and Dorazio, 2008; Kéry and Schaub, 2011). We extracted the modeled abundance from each iteration of the posterior ($N = 3{,}000$) and then calculated the species richness, Shannon diversity, and total abundance at each location. We then extracted median values and interquartile ranges across the 3,000 posteriors. Finally, we used GLMMs to assess effects of the three farm types (determined by interview data) on the species richness, Shannon diversity, and total abundance calculated from the N-mixture models, followed by Tukey *post-hoc* tests. We included the fraction of surrounding semi-natural habitat within 1 km as a covariate to account for landscape context and farm identity as a random effect to account for spatial autocorrelation among point count locations. All variables were modeled with Gaussian distributions. Total abundance was log-transformed to satisfy model normality assumptions. To propagate error uncertainty from the N-mixture model, metrics were weighted by the inverse of their interquartile ranges, as in Karp et al. (2018). Analyses were implemented in R (R Core Team, 2014). For more information about statistical methods used, see Appendix in **Supplementary Material**.

RESULTS

At the outset of this research, we sought to understand the factors influencing adoption of diversification practices for the organic lettuce sector of the California Central Coast *as a whole*. Indeed, several overarching trends emerged from our interviews, and we

TABLE 1 | Descriptive statistics of interviewed farmers.

	Number of farmers interviewed	Acreage farmed				Percentage of land leased (not owned)				Number of years farming			
		Median	**(Min–Max)**	**SE**	***n***	**Median**	**(Min–Max)**	**SE**	***n***	**Median**	**(Min–Max)**	**SE**	***n***
Limited resource	6	9.5	(4–20)	2.84	6	100%	(100–100%)	0	6	11	(9–40)	4.92	6
Wholesale	8	2000	(580–>10,000)	3659.99	7*	88%	(25–100%)	0.12	7*	40	(18–>70)	6.13	7*
Mid-scale diversified	6	74	(20–350)	58.95	6	31%	(0–100%)	0.17	6	28	(10–>30)	3.90	6

One grower did not provide this data.

TABLE 2 | Key characteristics of the farming model typology.

	Limited resource	**Large wholesale**	**Mid-scale diversified**
Size of farm	1–20 acres	500+ acres	20–350 acres
Economic pressure	High: limited resources	High: capital intensive, slim margins, high risk	Moderate: may have some economic buffer and options (e.g., multiple crops, markets)
Land tenure	Short by necessity (often only option)	Short by choice (need flexibility to adjust with markets)	Often longer-term leases and ownership
Biggest drivers of farming model	Economic (insecure access to land and other resources)	Economic (constraints from supply chain/buyers)	Ecological (health of overall farm system)
Use of diversification practices such as cover cropping, compost, complex rotations	Limited due to cost and lack of resources, insufficient land tenure to plan long term, information/knowledge barriers	Limited due to markets: lack of flexibility in cropping systems and planting schedules, food safety restrictions imposed by supply chain	Prevalent due to their importance to farming systems, availability of resources and information, and long-term tenure
Biodiversity	Some, mostly unplanned: diverse crops by necessity of opportunistic small scale marketing, natural or semi-natural components of farm often due to lack of time and resources for management	Minimal; biodiversity largely seen as a nuisance or hazard	A lot, much of it planned: due to importance to farming model, availability of resources and information, and long-term tenure
Mental model	Flexible; lack resources to set and meet precise goals	Often more mechanistic: speak of managing "carbon," "N," "nutrients"	Often ecological: speak of managing whole living systems (e.g., soil food web)
Degree of management and modification of landscape	Low, due to limited resources, time/labor, information	Total, pre-planned management of precisely controlled agroecosystem	Selective, flexible management, based on careful observation of agroecosystem with wild elements

present these in a forthcoming paper. However, as we analyzed interview transcripts, we began to identify a pattern: growers' approach to diversification practices seemed to fall into one of three categories. To try to get a better understanding of these three distinct adoption scenarios, we constructed a typology, stratifying our sample into three different groups (**Table 1**).

At first glance, this typology may appear to be based entirely on farm size. Farms in the first category are smaller than 20 acres, farms in the second category are larger than 500 acres, and farms in the third category fall somewhere in between. Yet, as we analyzed the interview responses of farmers in each of these three categories, we came to understand farm size as an emergent property of each category, rather than a defining characteristic. Moreover, we came to see these normative or ideal farm sizes for each category as highly contingent on social factors that have changed over time (and may well change again).

The central defining characteristic of each category in the typology was not farm size, then, but something we came to understand as a farming model (**Table 2**). Each of these farming models represented a distinct pathway through which farmers were able to navigate the structural conditions of organic lettuce farming on the California Central Coast (shaped by high land values, concentrated supply chains, and a robust alternative agriculture movement) and attempt to construct an economically viable operation. Each of these farming models integrated a business model for economic survival, an ecological model for agronomic performance, and a mental model of the farm ecosystem and how it should be managed. This integrated complex of models strongly influenced farmers' perception of diversification practices and their usefulness, their agency to apply or experiment with such practices, and the degree to which they had implemented them on their farm (**Table 3**).

TABLE 3 | Key themes in the perception and implementation of diversification practices.

Theme	Number of farmers discussing			Illustrative quote
	Limited resource ($N = 6$)	Large wholesale ($N = 8$)	Mid-scale diversified ($N = 6$)	
Economic pressures are a primary factor limiting my use of diversification practices	5	4	2	"We have to grow higher dollar cash crops because obviously, the price of everything is going up." (large wholesale) "We'd like to have it all covered, everything, but we don't have enough money to cover [crop] everything." (limited resource)
Short land tenure and high rent are a key factor limiting my use of diversification practices	3	2	1	"On subleased ground we're not composting because that's kind of a long-term strategy. And part of the reason we're not composting also is because we have really tight windows to work with." (large wholesale) "If the contract is extended, we should put coverage [cover crop] instead of compost, because the coverage sponges the earth very soft to work." (limited resource)
Markets are a key factor encouraging diversification practices on my farm	3	1	5	"When you're marketing the way that we do, to have a diversity of crops to market is a big benefit …. if you really wanted to look at tapping into some of the local markets, like stores, if you have a price list that you can send out with 20 items it's much easier for a store to make an order as opposed to having a price list with 4 or 5 items." (mid-scale) "Farmers' market customers, when they see a diverse display on your table they're like, 'Oh, I can probably find something I need here,' vs. only having only two or three things on your table." (limited resource)
Market requirements are a key factor limiting biodiversity on my farm	0	5	0	"Going into the organic side, those standards have all changed. As more big companies, what we would consider more corporate companies and farms, whatever else is out there that's gotten into those things, the tolerance levels got closer to zero. In the old days, when I first started organic, there was a certain tolerance level for a little bit of aphid, but that's not the case today.... I mean, I would prefer to still be using compost, but there's that idea that there might be E. coli out there." (large wholesale)
Crop plan includes 20 or more crops	0	1	6	"It is a long list [laughter]. We probably do, yeah, 50 or 60 different varieties of vegetables throughout the year, and we do some tree fruits." (mid-scale) "Oh, man. List of crops? Here. Let me grab the harvest sheet to help me." (mid-scale)
Hesitation about using compost due to food safety concerns	0	3	0	"We used to do quite a bit of composting. But that kind of falls under the same food safety regulations that they—[large wholesale buyers], they won't allow you to use any composting anymore because of the possibility of the *E. coli*." (large wholesale)
Hedgerows are desirable	1	2	6	"We have put in hedgerows along the borders of the fields for two reasons. Not just to benefit some of the services that a hedgerow can give for the crops, pest control, but also for buffering some of the practices from intruding or damaging some of the native habitat." (mid-scale)
Hedgerows are undesirable	0	4	0	"We've removed any hedgerows or anything because of the food safety issue." (large wholesale)

Below, we describe the three groups in our typology—limited resource, mid-scale diversified, and large scale wholesale—as well as some gray areas that emerge between these categories. Lastly, we present results from ecological surveys across our typology.

Limited Resource

Limited resource farms were shaped by several economic constraints, but also by farmers' ingenuity in adapting low-capital, low-input farming methods. The major economic

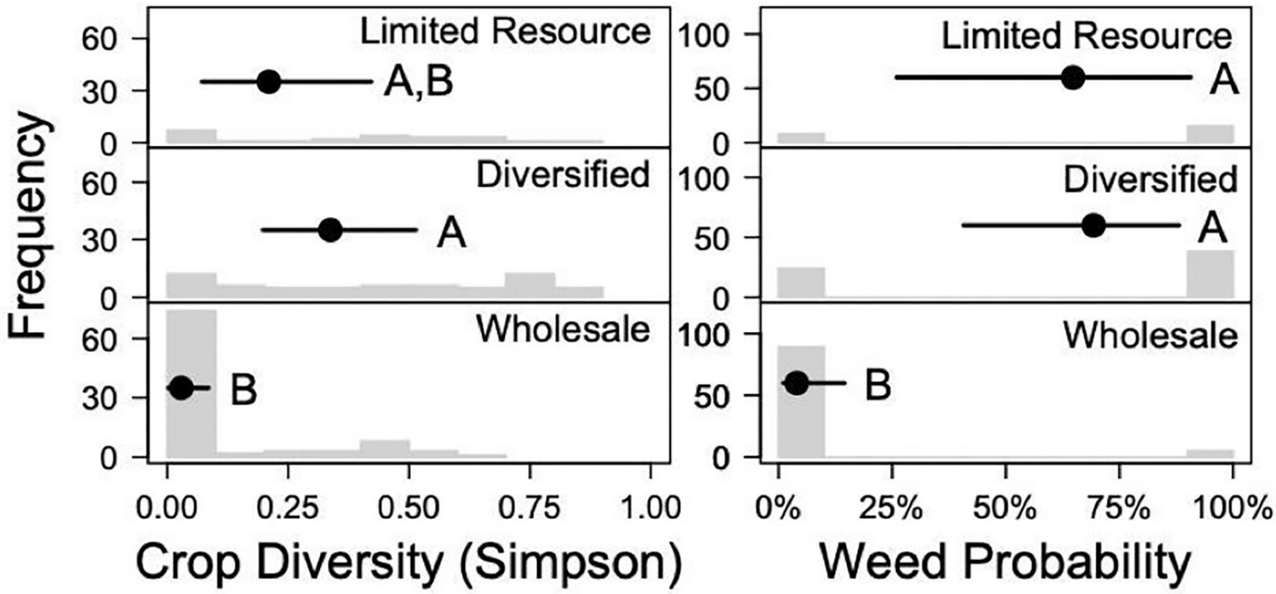

FIGURE 2 | Effects of farm types on crop diversity and "weediness." Left panels: Crop diversity (Simpson index) was significantly higher on diversified than wholesale farms, whereas limited resource farms grew only marginally more diverse crops than wholesale farms. Right panels: The probability that weeds occupied >5% cover within at least one crop type was also much higher on limited resource and diversified farms than on wholesale farms. Gray histograms depict distribution of raw data. Solid black points and lines indicate estimates and 95% confidence intervals from linear mixed models; letters denote significance under Tukey *posthoc* tests.

constraints limiting these farms were all related to land markets. In an area where agricultural land values are particularly high (Guthman, 2004), limited resource farmers told us they could only afford to rent small parcels, typically on 1–3 year leases. Echoing, Calo and Master (2016), nonwhite and immigrant farmers faced particularly stiff barriers accessing quality land and negotiating leases of more than a year or two. Short-term land tenure was hence a major limitation to adopting diversification practices that only pay off after multiple years. As one of the technical assistance providers we interviewed commented, "If you're leasing, you're not going to plant perennials ....I think about one of our clients who initially leased land and then ... was able to buy the land. And then as soon as she bought it, she started planting perennial borders, but it wasn't until she had that long-term land security that she started doing that." Farmers in this category also felt constant pressure to quickly intensify their production to generate cash, so as to keep up with the ever-present pressures of high lease payments. The result was often a more simplified crop rotation, with fewer (or no) cover crops. For these growers, maximizing limited acreage for production was a priority; using hedgerows and cover crops, which do not generate revenue, were in tension with this goal. One limited resource farmer explained the need to earn enough from the land to cover the cost of the lease: "We are talking 1,500, 2,000 dollars for the rent, and that is why people do not want to put coverage [cover crop], because they lose a lot of money [by not planting another cash crop]." The cost of purchasing inputs such as compost or cover crop seed, and potentially also the labor to manage these practices, was also cited as a barrier by some limited-resource farmers.

In general, limited resource farms fell somewhere in the middle of our sample with respect to both planned and unplanned biodiversity (**Figures 2**, **3**; **Supplementary Tables 1, 2**). Several of these farmers reported that they largely depended on direct markets that reward crop diversity; thus they tried to grow as many crops as they had the space and time to manage. Meanwhile, although these farmers had constrained ability to invest in hedgerows, floral strips to support beneficial insects, or other planned biodiversity beyond their crops, they frequently allowed for some degree of unplanned biodiversity. One farmer talked about the benefits of flowering plants, "either intentional plantings like that or we often let our crops go to flower .... and then things like weeds [laughter]. We have a lot of weeds as you can see."

The management strategy of these limited resource farmers could best be characterized as making do with what they had. Most limited resource farmers we spoke with were focusing their limited time and energy on high-priority tasks, which led to less intervention and landscape modification compared to other farming models. While this type of management could have ecological benefits, such as higher levels of unplanned biodiversity, it could also lead to weed and pest problems that could become difficult to control. Indeed, the probability of observing weeds growing amongst crops on limited resource farms was considerably higher than for large wholesale farms

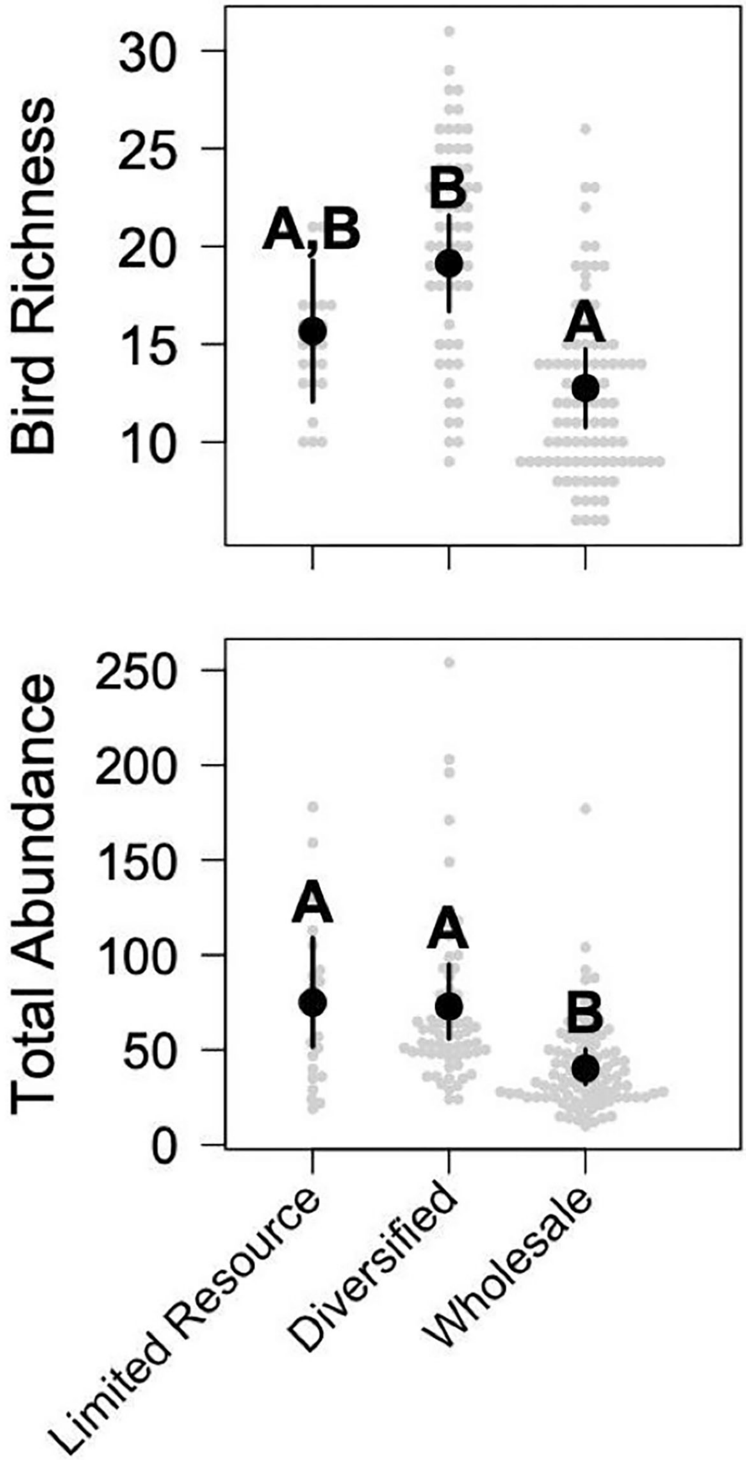

FIGURE 3 | Effects of farm types on bird communities. Bird species richness and abundance were significantly higher on diversified than wholesale farms. Bird communities on limited resource farms had intermediate levels of diversified but high abundances, equivalent to diversified farms and significantly higher than whole farms. Gray points indicate richness (top panel) and total abundance (bottom panel) estimates at all point-count locations from N-mixture models. Solid black points and lines indicate estimates and 95% confidence intervals from linear mixed models; letters denote significance under Tukey *posthoc* tests.

(**Figure 2**). Given their precarious access to necessary resources (land, labor, and capital), these farmers expressed the need to be scrappy and opportunistic, in order to cope with pervasive instability. "In general, what's planned, many times it doesn't happen," one limited resource farmer told us, in response to a question about crop rotation. "One product finishes and then I plant what I have accessible. What would be ideal is lettuce with broccoli, cauliflower, then after that, kale, but sometimes it doesn't go as planned." When asked about future plans or aspirations, however, several expressed a goal of stabilizing their business as a diversified, small-scale livelihood farm. One of our interviews with a Spanish-speaking limited resource farmer was translated by the farmer's young son, who periodically added analysis and observations of his own. "If everything goes well and he's able to pay his debt," this farmer's son said, "he hopes to get more financing, more money to be able to use the full potential that he has, that he knows he could do."

Large Scale Wholesale

Farmers selling into the wholesale lettuce market (mostly on contracts) must manage large acreages in order to meet their buyers' demands for large, consistent volumes of product delivered on time. Large acreages are also necessary for these farmers to earn a living on the slim margins of the wholesale market (Tourte et al., 2017). In order to meet these demands, several of these farmers were managing multiple, spatially separated parcels, sometimes across multiple counties. Given their large scale, farms in this category have an outsized influence on the sector and regional economy as a whole. The 2012 Agricultural Census, for example, found that lettuce farms in Monterey County averaged 983 crop-acres, and Calvin et al. (2017) surveyed five leafy greens grower-shippers in the region that averaged $196 million in annual fresh produce sales.

Much like the limited resource farms we visited, these large-scale wholesale farms (and their approach to diversification practices) were also strongly shaped by economic constraints. While most of these farmers had access to far more capital than limited resource farmers, the margins between their revenue and their costs were uncertain and could easily result in a loss if price or yield dipped too low (Tourte et al., 2009, 2019), leading them to express similar worries about economic vulnerability and lack of financial buffers. In terms strikingly similar to those used by the limited resource farmers we spoke with, these wholesale farmers expressed constant worries about factors beyond their control that could make their farms financially unviable. "It's pins and needles for us as growers," one of these large wholesale farmers told us. "This business is slim margins."

Again, mirroring limited resource farmers, wholesale farmers we spoke with were often renting their land on short (1–3 year) leases, which limited their interest in diversification practices that require many more years to implement and achieve a significant return on investment. However, unlike most of the limited resource farmers we interviewed, several wholesale farmers expressed a preference for short-term leases, as it gave them the flexibility to adjust quickly to changes in markets and supply chain requirements. As one grower recalled of a downturn in the lettuce market, "We found ourselves with declining contracts because of declining consumption, and we were about 1,500 acres long on ground. Luckily, we had some short-term leases, so we could shed some of that ground."

In general, the picture that emerged from our conversations with large-scale wholesale growers was one in which land value still constituted a key economic constraint, as it did for limited resource farmers, but markets played an even stronger role in their decisions about whether to adopt diversification practices. For wholesale farmers, their business model revolved around the demands of their buyers, who largely determine what, when, and how they grow. "We're pretty much forced to abide by the rules that are given to us based on what your shipper is requesting," said one of these large growers, who lamented wholesalers' low tolerance for biodiversity due to stringent food safety protocols. "But we do try to give them, to try to convey a message to them to please pass that onto their customer, that realistically, there's certain things we can't mitigate. But food safety, you don't question too much. But I'd like to go back to [the idea that] we're not farming in the lab."

Wholesale farmers described minimal use of diversification practices, a choice they largely ascribed to the demands of their buyers. These farmers described rigid planting and harvest schedules that discouraged cover cropping, as well as meager wholesale markets for diverse rotation crops. As one grower explained about two crops he would ideally like to grow in rotation with each other, "[T]he demand for [romaine] hearts seems to be increasing faster than the demand for [broccoli] rabe. And, so that in the future can definitely lead to unsustainable situations." Wholesale buyers, these farmers told us, tended to discourage or even prohibit compost and hedgerows due to food safety concerns, while cover crops were considered a nuisance for harvest logistics and timing.

In the face of these supply chain constraints, both planned and unplanned biodiversity were typically minimal on these farms. In interviews, growers on these farms frequently characterized biodiversity as a liability rather than an asset, particularly in the wake of more stringent food safety audits. "We don't want to see them," one grower answered bluntly, in response to a question about experience with birds and other wildlife. "What used to be a windbreak is now a hazard," another large wholesale grower explained. "So that's why you see a lot of trees being topped."

In describing their management objectives, farmers selling into large volume wholesale markets were the polar opposite of limited resource farmers. These large-scale wholesale farmers laid out pre-planned strategies for intensive management and landscape modification to meet precise goals, scheduling farm operations well ahead of time and supplying carefully measured nutrients through external inputs. They emphasized "cleanliness" and control, keeping weeds to a bare minimum. These farmers frequently expressed the view that land can sustain productivity more or less indefinitely through rational management, and that soil can withstand and bounce back from occasional challenges such as poorly timed tillage. As one grower said, "soil has this unimaginable power. It's the most resilient thing in the world, so I hate to say it, but you can beat it up pretty bad and it's going to bounce back pretty quickly if you treat it right. At least around here because we have ideal conditions for soil to regenerate itself."

Mid-Scale Diversified

Distinct from these first two categories of farms, a third farming model emerged in the intermediate space between the challenges of operating a very small operation with limited resources and the stringent requirements and narrow margins of the large-scale wholesale market. We refer to these intermediate farms as "mid-scale diversified" operations, as they are characterized by highly diverse mixtures of both crops and markets, and in our study region, they tend to be larger than limited resource farms but smaller than farms that sell primarily or exclusively into wholesale markets.

Economic pressures related to land and markets were by no means absent from conversations with these mid-scale diversified farmers. As one of them put it, "farming has such a narrow margin that you're just sacrificing things all the time." However, mid-scale diversified growers tended to present these economic pressures as being moderated by the greater flexibility afforded by diverse crops and markets. "I've always felt like having a more diverse biological operation, you can reduce the ultimate loss by being able to hedge certain things that you wouldn't be able to if you didn't have that diversity in place," one mid-scale grower said. In general, these farms were well-positioned to access values-based markets that are more stable and lucrative (e.g., high-traffic farmers markets, high-end local retail). While some also sold into wholesale markets, this was typically not a primary market channel but rather a means of unloading surplus. Direct and regional markets worked well for these growers because they had a good story to tell about their ecological management strategies, and had succeeded in engaging loyal customers. As one mid-scale diversified grower expressed, "[C]hoosing clients that are understanding of what goes into achieving a certain quality, and especially understanding organic practices and ecologically supportive practices to achieve that quality, that's where I think it becomes very interesting to engage and sell." While these diverse, values-based markets were a key source of economic stability for mid-scale diversified farms, by far their greatest source of stability was their long-term land tenure. Most of these farmers owned some or all of their land, and those who rented had long-term leases. These farmers consistently expressed that long-term land tenure was necessary in order to invest in the ecological health of their farms. "Every time I lease a piece of ground, it must be a minimum of five years," one mid-scale grower said. "I don't do any one year, two year [leases]. I think it's a waste of time if this is what I do for a living."

With economic pressures moderated enough to give them some flexibility to experiment, these mid-scale diversified farmers were largely designing their farming models around the goal of agroecosystem health. For example, they described crop rotations that were planned to improve soil health and provide habitat for pollinators and beneficial insects. "One of the things I'm probably the proudest of in our tenure here on this home farm is providing habitat and diversity," said one mid-scale grower. "It was a very barren place when we first got here … and it took a lot of work to clean the place up for it first of all and then to plant various habitats in the form of hedgerows and riparian waterways." Mid-scale diversified farmers were also more likely than farmers in either of the other two groups to characterize ecological and economic health as tightly coupled, rather than in conflict with one another. As one mid-scale diversified farmer expressed, "I'm pretty convinced that most of the things we've done over the years to have more of a biological system for our insect control, more biology in our soils, more diversity, in many levels have helped us be a profitable farm."

In describing their management objectives, mid-scale diversified farmers tended to reference biological factors before economic factors. These farmers described (and we observed) high levels of both planned and unplanned biodiversity, from complex crop rotations to intentional plantings of alyssum (a flower that hosts beneficial insects) to native plant hedgerows to unmanaged wild areas. They also spoke in more ecological and holistic terms, about things like managing "the soil food web" rather than meeting targets for nitrogen or carbon. The degree of landscape modification on mid-scale diversified farms fell somewhere between the light touch of limited resource farmers and the precise, controlled systems on wholesale farms. In general, we found mid-scale diversified farmers practicing selective, flexible management, based on careful observation. Thus, while this farm type was in some ways less stringently managed than a wholesale-oriented farm, management of these diversified farms also seemed to require more time and knowledge. For example, one farmer said, "I think the edges of every field that has native habitats or hedgerows are inviting to animals that can have an impact on your productive, cultivated fields, and it's a matter of understanding what the cycles are. And so first, what causes the damage, of course. What organisms cause the damage? What's the extent of the damage? And then understanding whether you can either live with that interaction or if you need to really control it, then understand the cycle. And you can plant certain things by understanding those cycles so you don't have to really kind of pursue drastic measures of exclusion or other practices, trapping, or things like that." These farmers weren't necessarily more knowledgeable than limited resource or wholesale farmers, but they were able to stay in one place long enough to experiment and make longitudinal observations, and they were also able to devote a greater share of their mental energy to ecological (rather than strictly economic or administrative) matters.

Gray Areas and Transitions Between Farming Models

By and large, limited resource farms and mid-scale diversified farms in our study were fairly consistent with the descriptions above, with clear distinctions between the two groups. We did interview one farmer who we categorized as limited resource, but who had recently secured a long-term lease and more stable markets, perhaps signaling a potential transition into the mid-scale diversified category.

The most noticeable gray areas in the typology came up in interviews with large scale wholesale growers who had been farming for a long time. Several of these farmers had retained some of the diversification practices (or at least memories and positive views of these practices) that they had used earlier in their careers. In some cases, they explained that they had shifted practices as they scaled up and became more reliant on wholesale markets. A number of them also attributed their shifting practices to changes in these wholesale markets, as markets tightened protocols, particularly around food safety. Those wholesale growers who insisted on higher levels of biodiversity than their buyers preferred were aware that they were cutting against the grain. "On the receiving side, one thing that we're trying to kind of educate on is that not every bug that they see is bad," one grower explained. "Last year, there were beneficial larvae. And so they were getting kind of scared, and they were holding up our shipments. But they didn't know that they were good beneficials."

One other notable gray area in this category was a large-scale wholesale grower who had managed to support diversified crop rotations through highly diverse wholesale markets and a small segment of direct markets. "I think the diversification is one of our biggest assets," this grower said. "Because we have so many crops, you'll never see us plant lettuce behind lettuce .... the crop rotation keeps us from getting diseases." This grower had some things in common with other wholesale growers (e.g., high percentage of leased land, large acreage, multiple parcels), but was able to incorporate many of the soil health and diversification practices utilized by mid-scale growers, including cover crops and compost. Unique among our sample, this large-scale grower had successfully negotiated long-term leases and contracts with buyers that suited this diversified farming model.

Ecological Surveys

While we constructed the typology based on farmers' descriptions of their goals and practices, we also observed ecological differences in crop diversity, weediness, and avian biodiversity among farm types. These ecological data largely corroborate the distinct typologies that emerged from interviews. We identified multiple differences in plant and bird diversity between mid-scale diversified and wholesale farms, fewer differences between limited resource and wholesale farms, and no significant differences between limited resource and mid-scale diversified farms.

We found that crop diversity was significantly higher on mid-scale diversified farms than on wholesale farms ($T = 4.51$, $P < 0.01$), with limited resource farms hosting more intermediate levels of diversity that were marginally higher compared to wholesale farms ($T = 2.55$, $P = 0.06$; **Figure 2**; **Supplementary Table 1**). Crop field weediness was higher on limited resource ($T = 3.48$, $P < 0.01$) and diversified farms ($T = 4.28$, $P < 0.01$) compared to wholesale farms (**Figure 2**; **Supplementary Table 1**).

Avian species richness followed the pattern found in crop diversity. Mid-scale diversified farms had higher bird species richness than wholesale farms ($T = 3.95$, $P < 0.01$; **Figure 3**; **Supplementary Table 2**) and limited resource farms had intermediate species richness that was not significantly different than the other farm types. Shannon diversity also increased from wholesale to limited resource to mid-scale diversified farms, but this trend was not significant ($P > 0.05$; **Supplementary Table 2**). Lastly, wholesale farms had lower bird abundance than limited resource ($T = 0.63$; $P = 0.01$) and mid-scale diversified farms ($T = 0.6$, $P < 0.01$); bird abundance was similar on limited resource and diversified farms ($T = 0.03$, $P = 0.99$; **Figure 3**; **Supplementary Table 2**).

DISCUSSION

Mid-Scale Diversified Farms Lead Adoption of Diversification Practices

Among the farms in our study, mid-scale diversified farms clearly emerged as leaders in adoption of diversification practices, which resulted in higher levels of both planned diversity (e.g., crop diversity) and unplanned diversity. This diversity may underpin high levels of avian species richness on mid-scale diversified farms which was nearly 50% higher compared to wholesale farms and 20% higher compared to limited resource farms (**Figure 3**). Indeed, these farms were structured around the principle of diversity, from the multitude of crops grown to the wide array of markets for which those crops were destined. Biodiversity and ecosystem services were central to the agronomic strategies of these farms, apparently creating positive feedback loops between economic and ecological dimensions of the farm operation.

Given the challenges with adopting diversification practices that we observed on both very large and very small farms in our study, and the relatively high adoption on farms with roughly intermediate acreage (20–350 acres), it would be tempting to attribute a causal relationship between farm size and adoption of diversification practices. Indeed, we could have structured our typology entirely around size. However, we suggest the stronger explanation for these mid-scale farms' adoption of diversification practices is not their size *per se*, but the deeper drivers of their farming model. Treating farm size as a dependent variable *alongside* diversification practice adoption allows for assessing what independent variables might drive them both. In the case of our study, the clearest causal factor underlying mid-scale farmers' adoption of diversification practices was their degree of agency.

What was perhaps most striking about our interviews with these mid-scale diversified farmers was the degree to which they spoke about making choices. They made choices about how they wanted to design their farming systems and crop rotations. They made choices about where they wanted to sell these crops. They also had the agency to value and promote forms of biodiversity that might directly benefit their farm, even in ways that are hard to measure (Kremen, 2005).

The key enabling factors that permitted these farmers to choose diversification were secure land tenure, adequate access to capital and resources, and a diverse range of buyers who shared their values and were willing to pay a premium. Supported by these three pillars, mid-scale growers had the economic security to navigate the challenges and uncertainties associated with highly biodiverse farms that are in a constant dynamic relationship with natural cycles. In a way, these mid-scale farmers had enough agency to allow their agroecosystems some agency of their own.

How Other Farmers Could Adopt More Diversification Practices

Researchers often look to such "lighthouse farms" or "early adopters" for clues about how other farms might transition to using more diversification practices (Nicholls et al., 2004). In the past, many such analyses have tended to focus on individual characteristics of such farms and farmers (Gould et al., 1989; Warriner and Moul, 1992; Napier and Camboni, 1993; Traoré et al., 1998). Do they take more risks? Do they have more education? In a number of cases, mid-scale diversified farmers on the California Central Coast have indeed taken significant risks or foregone short-term economic gains, based on strong commitments to an ecological model of farming and a willingness to experiment. For several in this group, commitments to biodiversity preceded their entry into agriculture, and these commitments may have even been one of the primary reasons they took up farming. However, if we want to learn how other farmers can adopt more diversification practices, we think it may be more fruitful to ask: what are the barriers to the enabling factors that have allowed these mid-scale farmers to exercise their agency in favor of diversification, and how can these barriers be overcome?

For the limited resource farmers we interviewed, the main barriers were secure access to land, capital, and other resources. For the most part, these farmers were structurally marginalized within a larger economic system that made it extremely difficult for them to access credit or build up capital. For large-scale farmers selling into wholesale markets, on the other hand, the barriers to diversification had more to do with their exposure to the demands of industrial supply chains. They lacked agency over their markets, which in turn strongly constrained their agency over their farms. Interventions aimed at helping farmers in our study area adopt diversification practices can be tailored to these two very different sets of barriers.

For small-scale farmers, policies should aim to alleviate resource limitations for adoption of practices (e.g., easier application processes for incentive programs), and work to help farmers achieve longer-term and secure land tenure (Calo and Master, 2016; Carlisle et al., 2019). In addition to land and monetary supports, policies should also prioritize secure access to water, technical assistance, and markets. These supports should not necessarily operate with the intention of helping farmers scale up and increase their farm size, as this may not be the goal for some small-scale farmers (Minkoff-Zern, 2019). Rather, the goal should be to alleviate the financial and resource limitations that prevent them from adopting more conservation practices that are often in line with their ecological values, but economically beyond their reach.

Further, expansion and streamlining of existing programs (cost-share, technical assistance, local food programs) would benefit smaller operations. Many farmers are unaware of federal and state incentive programs, and the difficulty of navigating them may create prohibitive barriers (McCann and Nunez, 2005). Even growers who are aware of such programs may not utilize them unless they hear positive feedback about conservation programs from farming peers (Prokopy et al., 2019). Thus, greater efforts should be made to publicize programs, provide enrollment assistance, and create opportunities and social structures for farmer-to-farmer sharing of personal experiences with such programs. Groups like The University of California Cooperative Extension, Kitchen Table Advisors, California FarmLink, and the Agriculture and Land-based Training Association (ALBA) provide such services for limited resource farmers in the California Central Coast region, and we know of at least one mid-scale farmer in our study who worked with these groups to build up their farm operation. These models should be expanded and better supported by public infrastructure.

Large-scale wholesale farmers, meanwhile, need help negotiating and adjusting the demands of their supply chains. Assistance is needed to build more robust alternative markets that value and encourage diversification, for example through public procurement policies for schools and other public institutions (Lo and Delwiche, 2016). Policymakers can also leverage regulations, such as water quality policies (Dowd et al., 2008; Harter, 2015; Drevno, 2018), that force large scale wholesale buyers to utilize diversification practices to reduce pollutants on their farms. Food safety standards (particularly those enforced by third-party audits required by wholesale buyers) clearly play an important role in discouraging diversification practices on these farms, so this is also a key arena for intervention (Olimpi et al., 2019).

While direct incentives for implementing diversification practices may assist some large-scale growers, the size of incentive that would be meaningful to a small grower may not be meaningful to a large grower, who has the weigh to amount of the incentive against the expenses and potential risk involved across a highly capital-intensive operation. Our interviews with large-scale farmers selling into the wholesale market were largely consistent with interviews conducted by Medina et al. (2020) among a group of 10 conservation-minded Iowa farmers, mostly categorized as large-scale family farms (320–5,000 acres). Both groups of farmers expressed that the financial incentives offered by USDA programs such as Environmental Quality Incentives Program and Conservation Stewardship Program are simply not large enough to incentivize changes in farming practices, and that greater incentives and program flexibility would benefit program adoption. Along these lines, a case study of cover cropping in Maryland showed that adoption of this practice rose as per-acre payments and program flexibility (i.e., split payment timing, extending planting deadlines) increased (Bowman and Lynch, 2019). However, these researchers also found that additional increases in incentive payments may not yield the same impact beyond a certain point and existing cost-share programs are not significant enough to drive adoption of soil conservation practices.

These findings suggest that increasing adoption of diversification practices on larger farms may require supplementing the "pull" of incentives with the "push" of regulatory mandates. Existing regulatory programs that could play a role in this process include the Irrigated Lands Regulatory Program in California, which allows for regionally-specific requirements and strategies for reducing water pollution (California Regional Water Quality Control Board: Central Coast Region, 2021). While no equivalent regulatory program exists to protect soil health, new or even existing regulatory programs could recognize the multiple benefits of diversification practices in a number of ways. Such regulatory programs could credit growers for adopting regionally appropriate conservation practices such as planting of non-crop diversity (e.g., winter cover crops to reduce nitrate leaching). These programs could work to clarify the framework surrounding food safety and allow growers more freedom to use biological inputs such as compost. Wholesalers often dictate their own food safety standards, which has dramatically decreased non-crop vegetation and use of compost and manure due to their perceived, but unsubstantiated, tie to food-borne pathogens (Karp et al., 2015; Baur et al., 2016). Previous work in this region found that food safety standards imposed by buyers impede regional sustainability outcomes (Olimpi et al., 2019). Under such conditions, it is likely that no amount of incentives will lead wholesale growers to adopt more diversification practices for fear of losing their buyers.

While regulatory measures are generally less popular among growers than incentive programs, steps can be taken to build support. Growers are not homogeneous in their attitudes toward regulation, and subjective norms—farmers' belief that other farmers think a given policy is necessary—strongly influence support for regulatory measures (Niles and Wagner, 2019). This finding suggests that creating venues for farmer-to-farmer dialogue about the need for various regulatory measures may be important for driving policy support.

By focusing on these key enabling factors, we believe it is possible to encourage diversification practices on farms at a variety of scales on California's Central Coast. We do not believe that the smaller-scale farmers we spoke to necessarily need to acquire more land to achieve a diversification "sweet spot," though they typically need more secure tenure. Nor are we convinced that larger scale farmers necessarily need to scale down their operations. Under current structural conditions, roughly "mid-scale" acreages between 20 and 350 acres are clearly more conducive to farming models that emphasize biodiversity. But as we understand it, this mid-range "sweet spot" is neither an ecological nor economic first principle, but rather the highly contingent result of current opportunities to access enabling factors under existing structural conditions.

Beyond the Central Coast

We believe that our methodological process may be useful to researchers in other regions who share our interest in adoption of diversification and soil health practices, and how adoption influences ecological outcomes. We encourage researchers to ask questions that allow farmers to identify structural barriers and how they are adapting or adjusting to these barriers. We further encourage researchers to consider how farmers are differentially impacted by these structural barriers, and whether it might make sense to construct a "farming model" typology, such as the one we have built here. When analyzing qualitative data, we encourage researchers to identify groups of farmers that have more fully adopted diversification practices, and to identify the enabling factors that have made this adoption possible. We also encourage researchers to consider what interventions might extend these enabling factors to other groups of farmers whose agency to adopt diversification practices has been limited. Finally, our initial effort to integrate ecological surveys and interviews illustrates how our typology may have tangible ecological outcomes. Future work should build on this analysis to explore the extent to which the use of diversified practices may create observable environmental outcomes, and how the perception of these outcomes may shape future management decisions. Such integration of quantitative and qualitative frameworks represents an important avenue for deepening understanding of these complex socio-ecological systems.

While the specific findings of this study are particular to organic lettuce farms on California's' Central Coast, the finding that mid-scale farms are the most likely within our study region to adopt diversification practices is particularly interesting in the context of the structural shift observed in the U.S. food system over the last half-century, characterized by a bimodal distribution of very large and very small farming operations and an ever shrinking "agriculture of the middle" (Kirschenmann et al., 2008; Lyson et al., 2008). The dominant production system in U.S. agriculture currently locks many farmers on a pathway toward large scale, input-dependent systems (IPES-Food, 2018; Anderson et al., 2019; Petersen-Rockney et al., 2021). This type of agriculture is prevalent both in the conventional and organic agricultural sectors, particularly when synthetic inputs can be replaced with natural and organic-certified inputs, as in lettuce and other crops in California (Guthman, 2004; Kremen and Miles, 2012). Meanwhile, smaller farms are often limited in their ability to adopt more sustainable practices by resource constraints and insecure land tenure. In brief, the Central Coast of California is one of many U.S. agricultural regions where the demands of consolidated food supply chains have pressured farms to grow ever larger, while simultaneously spurring an alternative agriculture movement that is still actively struggling to adequately support local food systems and economically marginalized small farms. In such bimodal environments, progress toward diversification will require an understanding of the distinct challenges faced by farmers on either side of the spectrum, with particular attention to the enabling conditions that allow some farmers to choose farming models and scales that are neither too big nor too small for diversification, but just right.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Committee for Protection of Human Subjects. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LC collected and analyzed qualitative data. KE and LC led writing and revision of the paper and managed collaborative process among co-authors. TB guided research process for the paper and contributed to writing. TB, AI, DK, and CK designed overall project, wrote the grant for funding, and provided guidance on methods, analysis, and our collaborative process. DK, AK, and EO integrated ecological data, including original ecological data collection, analysis, and figure and table creation. PB, JO, and HW provided comments, edits, and intellectual contributions to the larger project and to this paper. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.734088/full#supplementary-material

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