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Time and technique assessments of labor productivity on diversified organic vegetable farms using a comparative case study approach

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Abstract
As regional food purchasing continues to gain consumer interest, an increasing number of diversified vegetable farms have emerged to meet market demand. Many of the small- and midscale vegetable farms selling into local markets, however, face continued challenges concerning the financial decision-making and the viability of their operations. Greater understanding of the consequences of financial, labor, and production-management decisions has the potential to improve the long-term success of these farms. In this exploratory work utilizing a comparative case study approach involving 10 diversified vegetable farms, we conducted time and technique studies to assess labor productivity as related to different farm labor and production management decisions. We focused our analysis on three specific activities (transplanting, harvest, and postharvest handling) for five common crops (broccoli, carrots, lettuce, peppers, and squash). Our results showed tremendous farm-to-farm variation in labor productivity, reflecting the diversity of approaches to production and

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management. Both mechanization and farm size influenced the time required to complete production and postharvest activities; however, these relationships were not consistent across all crops and activities. While time and technique studies can help farmers to more effectively strategize innovations in production practices and equipment purchases, farm-specific considerations such as crew size, farm land base, and worker welfare will remain important factors for farmers in assessing the consequences of mechanizing any process and of changing their particular management strategy, as well as the appropriateness of adopting technologies in the context of farm scale and resources. Challenges and weaknesses associated with on-farm participatory time and technique studies were identified, leading to recommendations to create a more feasible system for similar data-collection efforts. The data generated by further expansion on our approach can provide diversified vegetable farmers, food system development professionals, and policy-makers with an additional information to contribute to the successful growth and financial status of diversified vegetable farms serving as vital components of strong local and regional food systems.

Keywords
Time and Technique Studies; Cost of Production; Organic Agriculture; Diversified Vegetable Farming; Local and Regional Food Systems; Scaling Up

Introduction

Vegetable farms make up an important sector of regional food markets, representing almost a third of local food sales (Low et al., 2015). Despite the growth of local and regional food systems, many small- to midscale vegetable farms provide low wages to both farmers and their farm employees, thus providing minimal incentive for additional farmers to enter these expanding markets. According to the 2012 Census of Agriculture, of the 163,675 "local food farms" selling into regional markets, 85 percent had a gross cash farm income below US$75,000, and only five percent had a gross cash farm income above US$350,000 (U.S. Department of Agriculture [USDA], 2012). While, except at the bottom of the range, gross income may not reflect the net returns on these farms, many farmers may not adequately account for their labor when estimating production expenses, thus insufficiently pricing their product to allow themselves to earn a living wage (Oberholtzer, 2004; Ostrom, 2007; Schreck, Getz, & Feenstra, 2006; Tegtmeier & Duffy, 2005). In addition to other key factors (such as market-driven price ceilings), underestimated and undervalued labor costs can contribute to farm owner hourly wages falling as low as US$3.60 per hour (Berkey, 2015; Galt, Christensen, Bradley, Simpson, & Munden-Dixon, 2015; Hendrickson, 2005; Ostrom, 2007). Practical production cost estimation tools can help enable diversified vegetable farmers, food system development professionals, and policy-makers to assess the economic viability of farms and to identify practices that can strengthen farm profitability and, more broadly, our local and regional food systems.

Estimating labor needs is an important component of strategic growth of farms, with several studies demonstrating the difficulty in profitably managing labor needs at an intermediate scale (Hendrickson, 2005; Silva, Claypool, Munsch, Hendrickson, Mitchell, & Mills, 2014). In his study of 19 Midwestern vegetable farms, Hendrickson (2005) observed that the midscale farm was, perhaps, a more difficult scale to maintain profitability as compared to other scales of diversified vegetable farms. The midscale farms, ranging from three to 12 acres (1.2 to 4.9 hectares), had the lowest three-year average annual gross sales of the three scales of farm, at US$11,121 per acre. The midscale farms also had notably higher hours per acre of labor inputs as compared to larger-scale farms, and a higher percentage of labor hours performed by the owner than either small-scale "market gardens" or larger-scale farms. Together, these three observations (decline in average gross sales, higher labor hours per acre, and higher owner labor hours) illustrate the challenge of balancing labor costs and management at the intermediate scale of diversified vegetable farming. Yet this scale of farm is a critical element in the continued growth and stability of regional food purchasing. These challenges may be offset by scale-appropriate and cost-effective technologies for this farm size (Revkin, 2014), as well as by policies that encourage markets, price structures, and purchasing agreements to support mid-scale diversified vegetable farms (Daniels, 2017).

The importance of labor-cost accounting in price determination on diversified vegetable farms is further amplified by the relative proportion of this expense to the overall cost of production. Studies documenting the costs of production on diversified vegetable farms have shown that labor accounts for a significant proportion of the costs, making up 65 to 75 percent on diversified vegetable farms versus 42 percent of production expenses on specialized vegetable farms (Ali & Lucier, 2008; Calvin & Martin, 2010; Chase, 2012; Hardesty, 2007; Hendrickson, 2005; Le Roux, Schmit, Roth, & Streeter, 2010). Labor inputs can vary widely across diversified vegetables farms, as shown by a study conducted by Hendrickson (2005) that documented ranges from 187 to 1,211 labor hours per ha^{-1}. These differences are affected by a host of factors, including variation in production and marketing approaches, farm size, and level of mechanization (Lohr & Park, 2009). Additionally, defining a standard value for labor costs associated with the production of specific crops on diversified vegetable farms may not be particularly useful due to variation in the managerial ability of farmers and/or farm employees; labor inputs are not only influenced by the size of labor crews designated to production and harvesting tasks, but also by the wide knowledge and skill base of operators, managers, and workers (Buck, Getz, & Guthman, 1997; Escalante & Santos, 2010; Hendrickson, 2005; Navarrete, Dupré, & Lamine, 2015; Pates & Artz, 2014).

Labor needs, and the related estimation of labor costs, on diversified vegetable farms are further influenced by a farm's level of mechanization. Mechanization tends to be more prevalent on farms with more specialized (rather than diverse) crop portfolios (Pates & Artz, 2014). Few studies have been conducted on the relationship between mechanization and growth of diversified vegetable farms, and the subsequent impacts on labor costs. In their study of Midwestern vegetable farms, Pates and Artz (2014) found that increased mechanization was associated with an overall increase in farm size. Decreased costs, reduced effort, improved timeliness of operations, labor cost savings, and mitigation of the lack of viable hand labor alternatives were cited by farmers as important factors in their decision to mechanize. Mechanization did not completely eliminate the need for labor, particularly during harvest, nor did it always have significant labor or cost savings.

Enterprise budgets have been a standard tool for evaluating production costs on farms and have served as economic decision-making tools for farmers (Connor & Rangarajan, 2009). However, adopting generalized enterprise budgets may not be the most appropriate approach to evaluating the costs of production associated with the highly diversified and complex cropping practices that characterize diversified farms selling into multiple market channels. Much of the variability related to differences in cropping and production strategies results from management differences leading to different labor needs and efficiencies, which can significantly affect the accuracy of generalized enterprise budgets as compared to the realized values for a given farm. As labor costs compose a significant proportion of the costs of production on diversified vegetable farms, this factor creates significant variation in a given farm's calculated break-even prices. As an alternative, farm-specific cost-of-production evaluations may offer more appropriate and accurate information to guide the financial assessment of these operations, and subsequent decisions to improve profitability. The need for developing a more specialized approach to determine costs of production on diversified vegetable farms is heavily documented in recent scholarship and has also been cited as a priority by many farmers (Bozoğlu & Ceyhan, 2007; Conner & Rangarajan, 2009; Jacobsen, Escalante, & Jordan, 2010; Hendrickson, 2005; Silva et al., 2014).

As an alternative to more standard enterprise budgets, time studies offer a different approach to assessing labor inputs and costs on diversified vegetable farms. Numerous non-agricultural industries measure labor productivity using time studies, which estimate the time required to complete cycles of work. Such studies can inform strategies for improving overall productivity and profit, while also providing guidance for ergonomic interventions or other modes of assistance for workers.

While little literature exists on using time studies in agriculture, the methodology developed by the U.S. Department of Labor uses the technique in investigations of workplace compliance with labor laws. This methodology involves (1) identifying the components, tasks, and subtasks to be performed, including methods and procedures used to accomplish the respective tasks and types of equipment and supplies to be used; (2) determining a definite start and stop point for the task; and (3) timing the entire job cycle, including all preliminary activities (set-up time) and all postliminary duties (stowing of materials and equipment) to be performed on the job by the workers (U.S. Department of Labor, 2016).

The objective for this overall project was to assess labor productivity on working certified organic vegetable farms in Wisconsin, across a range of farm scales and levels of mechanization, using time and technique assessments within a comparative case study approach on 10 diversified vegetable farms, while concurrently identifying the strengths and weaknesses of this approach. The longer-term goals of this project were two-fold: (1) to begin to develop methodology that can be utilized by agricultural and food system professionals, as well as farmers, to assist local and regional food producers in making informed production decisions on their farms to improve the financial viability of their operations; and (2) to begin to develop benchmark values that can guide farmers regarding best management practices, mechanization purchases, and scaling-up decisions for their farms. With this information, we aimed to provide diversified vegetable farmers, food system development professionals, and policy-makers with an additional tool and source of data to contribute to the successful growth and financial status of these farms serving as vital components of strong local and regional food systems.

Methods

The methods of this study were approved by the University of Wisconsin-Madison's Institutional Review Board (IRB No. 2014-0885). To conduct time studies across a diverse representation of operations, labor data were collected on 10 certified organic diversified vegetable farms in Wisconsin, USA, throughout two production seasons, 2014 and 2015 (Table 1). Farmers were recruited initially using communication through the Fairshare Community Supported Agriculture Coalition (Madison, Wisconsin); from the first farms that volunteered for the study, additional farms were recruited using snowball sampling techniques. Farms were included to reflect a range of production scales, levels of mechanization, and management approaches representative of upper Midwestern organic farms. This included three small farms defined as 0 to 3 acres (0 to 1.2 ha),

Table 1. Demographic Profiles of 10 Certified Organic Diversified Vegetable Farms in Wisconsin, USA, Included in the Time and Technique Data Collection Efforts, 2014 and 2015

Farm	Farm size	Acres in vegetables	Farmer gender(s)	Age range	Years farming	CSA shares
A	Medium	7.0	Male	50+	20+	n/a
B	Medium	4.0	Male	40–49	10–20	450
C	Large	20.0	Male & Female	30–39	10–20	350
D	Small	1.5	Male & Female	20–29	6–10	36
E	Large	48.0	Male	30–39	10–20	440
F	Large	45.0	Male & Female	50+	20+	478
G	Medium	5.5	Male	30–39	6–10	168
H	Small	3.0	Female	50+	20+	33
I	Small	2.5	Male	20–29	>5	112
J	Medium	5.5	Male	20–29	6–10	195

Note: 1 acre=0.4 ha

four medium farms defined as 4 to 10 acres (1.6 to 4 ha), and three large farms defined as 10 to 50 acres (4 to 20.2 ha). All farms had a community supported agriculture (CSA) component to their operation, but varied in the other market avenues with which they engaged.

Time and technique studies were designed to measure the labor required for three specific model activities, selected for the relative standardization of practices across a wide range of farms: transplanting, harvesting, and postharvest handling (washing and packing). These activities were observed for five crops: broccoli, head lettuce, carrots, bell peppers, and summer squash; these crops were chosen to represent a diversity of crop families, growth habits, seasonality, and production and harvest techniques. We also measured the time required to pack CSA boxes. Activities for which we collected data, while not encompassing all aspects of farm operations, were chosen in consultation with a farmer advisory committee, which identified these points in production as key elements for strategic labor management. The observations for each activity by crop are enumerated in Table 2. Data were collected when activities represented large hired-labor needs during a growing season (e.g., during peak harvests and planting times) in order to best capture the impact of farm management strategies on labor productivity. Farmers communicated with the research team to schedule data collection for key events related to different activities. Data collection was avoided during extreme weather conditions (e.g., storms or extraordinary heat) to avoid the impact of extreme weather on labor productivity.

Data were collected using a cyclical measurement model, similar to the methodology used in the U.S. Department of Labor time studies. With a high degree of variability in labor efficiencies hypothesized to exist across farms, we collected data in "pulses" across the common activities described above, to compare labor efficiencies most effectively across farms of different scales, levels of mechanization, and employee management strategies, with the goal of estimating of labor productivity gains or losses across these different variables. A pulse was defined as one discreet activity for one crop (e.g., transplanting lettuce or harvesting carrots). For each pulse, we recorded the total time required to complete the pulse, as well as the time to complete shorter subsections of the pulse. We collected the time to complete each activity for every crop included in the study, plus CSA box packing. The time to complete each activity, not including travel to the field or idle time, was measured with stopwatches by research program staff who visited the farms while activities were occurring. A summary of the number of observations collected per activity and crop category (pulses) is included Table 2.

In addition to the time for completion of task, we recorded other production metrics, including appropriate unit of vegetable yield handled in a pulse (and in each individual trial); number of transplants and row feet for transplanting; units of vegetable harvested for harvest; units of vegetable washed and packed for postharvest; and number of boxes packed for CSA packing. We also collected other descriptive information on the methods (hand or machine) and techniques employed. Quantitative and qualitative characteristics with respect to the work force included crew size, experience (number of seasons employed), presence of crew leaders, presence of volunteers or worker-shares, presence of farmer-owner, and division of labor. Additional variables, including environmental conditions and market channels, were also noted. A complete list of data categories can be found in Table 3.

Interviews with the participating farmers provided supplemental information on farm management, farmer experience, crew numbers and experience, wages, market channels, and pricing. This information provided more context for each farm when interpreting efficiencies and differences between operations.

Data were analyzed to assess four measures of labor productivity: time per output, time per output per person, output per hour, and output per hour per person. The first two measures (time per output and time per output per person) contain the same information as the last two measures (output per hour and output per hour per person), since the measures are simply reciprocals of one another. While the participating farmers found that data summaries in the form of time per output and time per output per person were more meaningful for their decision-making processes, measurements stated as output per hour and output per hour per person are more frequently used conventional measures of labor productivity by other industries (U.S. Department of Labor, 2016).

For transplanting activities, time per 100 row feet transplanted, time per 100 row feet transplanted per person, transplants per hour, and transplants per hour per person were calculated. For harvest activities, time per pound of vegetable harvested, time per unit of vegetable harvested per person, units of vegetable harvested per hour, and units of vegetable harvested per hour per person were calculated. For postharvest activities, time per unit of vegetable packed, time per unit of vegetable packed per person, units of vegetable packed per hour, and units of vegetable packed per hour per person were calculated. For CSA box packing, time per box packed, time per box packed per person, boxes packed per hour, and boxes packed per hour per person were calculated.

Statistical Analysis

Data was analyzed using JMP Pro software Version 9 (SAS Institute, 2011). Variables analyzed included level of mechanization, farm size, grower presence, new employee presence, and worker-share or volunteer presence. Level of mechanization was operationalized from the variable "Method." Usually, a binary variable was employed (e.g., hand v. machine), but for some pulses, more variation was present in the type of machine used, and so multiple categories summarized the range of machinery employed. Farm size was operation-alized from the number of acres in vegetable

Table 2. Numbers of Transplanting, Harvesting, and Postharvest Observations ("Pulses") by Crop, Characterized by Mechanization and Farm Size, on 10 Wisconsin Diversified Vegetable Farms for the 2014 and 2015 Seasons

		Broccoli	Carrots	Lettuce	Peppers	Squash
Transplanting	*Mechanization*					
	Hand	5	n/a	5	3	2
	Machine	4	n/a	5	3	4
	Farm Size					
	Small	3	n/a	3	2	1
	Medium	4	n/a	3	n/a	1
	Large	2	n/a	4	4	4
	Total	9	n/a	10	6	6
Harvesting	*Mechanization*					
	Hand	12	11	20	13	22
	Machine	1	10	n/a	n/a	2
	Farm Size					
	Small	n/a	6	2	3	7
	Medium	9	9	9	5	9
	Large	4	6	8	5	8
	Total	13	21	20	13	24
Postharvest	*Mechanization*					
	Hand	9	13	15	6	14
	Machine	0	10	n/a	5	2
	Farm Size					
	Small	n/a	7	1	2	7
	Medium	8	9	9	5	7
	Large	1	7	5	4	2
	Total	9	23	15	11	16

production on each farm. Grower presence was noted by a "yes" or "no" to indicate whether the grower was present for the timed activity. New employee presence was noted as "yes" or "no" to whether an employee was being trained on the activity and was participating in the activity for the first time. Worker-share or volunteer presence was noted as "yes" or "no" to whether a worker-share or volunteer or other nonpaid workers were participating in the activity.

This study was designed as a comparative case study with the primary goal of evaluating the feasibility of conducting time and technique assessments on vegetable farms as a method to determine labor efficiencies associated with production, harvest, and postharvest activities incorporating different approaches. With the limited data set that was developed, we also conducted a preliminary analysis to begin to determine the impact of farm mechanization and size on labor efficiencies for different production, harvest, and postharvest activities of five representative crops. One-way ANOVAs were conducted on all 15 pulses for each of the five different variables and for two labor productivity outcomes (output/hour and output/hour/person), for a total of 10 analyses per pulse. For each variable, significant differences were identified using a 5% and 10% significance level. While the contextual data analysis discussed below focuses on variables determined to be significant at the 5% level, significant values at the 10% level are presented within the tables to identify additional factors that may be affecting farm productivity on a practical level, but may not be detected due to

Table 3. Information Collected for Each Observation in Time and Technique Studies, Characterized by Activity, 2014 and 2015

General Information				
Environmental conditions: *Temperature, wind, precipitation, soil conditions*				
Bed conditions: *Number of beds, bed length, plastic mulch or bare ground, soil preparation (method and date)*				
Was the grower (farm owner/manager) present?				
Crew description: *Size, experience of crew members, presence of crew leader, information on the division of labor, rotation of tasks, if new members were being trained, if the crew included worker-shares*				
Activity-Specific Information				
	Transplant	**Harvest**	**Postharvest**	**CSA Box Packing**
Description of activity	Method: hand or machine	Method: hand or machine	Method: hand or machine	
	Equipment used	Equipment used	Equipment used	Equipment used
	Bed length	Selective harvest or complete harvest	What is being done	Total number and list of crops being packed
	Soil preparation (method and date)	Weed pressure level	Packaging Used	Packaging used
	Additional time spent watering and/or setting up irrigation	Postharvest handling in the field		
	Technique description	Technique description	Technique description	Technique description
Trial specific information	Crew number	Crew number	Crew number	Crew number
	Time per bed	Time per trial	Time per trial	Time per trial
	Rows per bed	Rows per bed	Amount accomplished	Type of share (half, full)
	In-row spacing	Bed length	Units	Number of boxes packed
	Transplants per bed	Yield: in pounds and units, when feasible	Market destination	Total number of shares
	Were transplants watered?	Market destination		
	Total time	Total time	Total time	Total time

small sample sizes and high standard deviations. A 10% level was used to determine statistical significance unless otherwise noted. Tukey's HSD tests were conducted to test the significant differences between each pair of categorizations within a variable. While the test assumes equal variance, the high level of variance in each pulse was assumed to satisfy this assumption. However, this analysis is not meant to be conclusive, but to provide initial observations to as where differences in farm labor efficiencies appear to exist and where further research efforts may be focused.

Results

Implementation and Feasibility of Time and Technique Assessments

As stated in the introduction, one of the primary goals of this study was to begin the development of benchmark values that could help guide farmers regarding the adoption of innovation, including best management practices, mechanization purchases, and scaling-up decisions for their farms. To accomplish this goal, a first objective involved the assessment of appropriate methodology with which to collect the data to create benchmark values. The development of baseline values requires a community-based approach, with cooperation from a group of farms with commonalities in production approaches and markets. Other efforts to develop these types of benchmarks have focused on farm finances, with one of the more extensive being FINBIN (Center for Farm Financial Management, 2016). The FINBIN database crowdsources and summarizes actual farm data entered by farmers using the FINPACK software that was developed for farm economic analysis. With access to the data summaries, farmers can compare their own farm financial information to the benchmarks created through information contributed from peer farms. These comparisons can indicate where farms may be excelling (in this case, using the metric of farm financial ratios) or falling short of success.

Whereas farms routinely collect farm financial data for tax purposes, facilitating the ability to crowdsource data, the collection of labor inputs by crop-specific activity is much less common on diversified vegetable farms (Silva, Hendrickson, Mitchell, & Bietila, 2017). Thus, a significant part of our efforts was focused on exploring possibility mechanisms with which to collect this data. For the purposes of this study, we used a participatory approach that involved both farmers and university employees, to assess not only the variability in the data that was collected, but also the feasibility of data collection efforts on farms by designated either on- or off-farm employees.

The 10 farms recruited to participate in the project remained in the study for both years within which data was collected. With two full-time university employees responsible for data collection and input throughout the production season, farm visits typically occurred 3 days week^{-1}, with one or two farm visits per day, depending on farm location and daily farm activities. Communication between farmers and data collectors occurred by telephone and email, typically 24–48 hours before a farm visit was scheduled. Data collectors recorded time to complete farm activities, as well as related data including crew size, amount of product planted, harvested, or packed, and other process details that may have affected the interpretation of results.

Across our case study of the 10 farms, we observed differences in crew sizes, divisions of labor, level of mechanization, and general management styles. For most activities, only one type of machine was used, resulting in a binary comparison. Transplanting machines consisted of waterwheel and carousel transplanters. Mechanized harvest equipment included digging machines (undercutters and carrot harvesters) for carrots, and mechanized harvest conveyor belts (suspended off a flatbed trailer hooked up to a tractor) for squash and broccoli. These belts allowed workers to place harvested produce onto the belt, reducing the amount of bending and the required time for crating. Postharvest washing and packing equipment included barrel washers and brush washers.

Transplanting Case Studies

For the task of transplanting, 31 discrete data pulses were collected to be included in the initial case study analysis, ranging across different approaches to mechanization (waterwheel transplanters and carousel transplanters) (Table 4).

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Table 4. Transplanting Labor Productivity Means Characterized by Mechanization and Farm Size and Effects of Five Variables on Labor Productivity for 10 Certified Organic Diversified Vegetable Farms in Wisconsin for Seasons 2014 and 2015

	Broccoli		Carrots	Lettuce [a]		Peppers		Squash	
	Mean ± SD	Median	Mean ± SD	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
Mechanization									
Hand	314 ±157	353	n/a	186 ± 97	154	113 ± 30	102	89 ± 21	89
Machine	421 ± 111	403	n/a	753 ± 356	846	438 ± 263	319	492 ± 188	570
Farm size									
Small	341 ± 37	340	n/a	232 ± 98 b	936	97 ± 9	97	103	
Medium	388 ± 225	460	n/a	164 ± 87 b	254	n/a		492 ± 188	104
Large	340 ± 43	340	n/a	878 ± 256 c	226	366 ± 260	287	89	
	<------				*p* > f				------>
Farm size	ns		n/a	0.0021		ns		n/a	ns
Mechanization	ns		n/a	0.0088		0.1010		0.0460	ns
Grower presence	ns		n/a	ns		ns		ns	ns
New employee?	ns		n/a	0.0197		ns		ns	ns
Worker shares/ Volunteers?	ns		n/a	0.0492		ns		ns	ns

ns Not significant at the 0.10 probability level
[a] Lettuce harvest measured in heads harvested per hour per person
Numbers in columns followed by different letters were significantly different at $p<0.10$ according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

Nonmechanized hand-scale tools used included Hatfield transplanters, rolling dibblers, and hand dibblers. Most farms used trays of soil plugs, requiring the dislodging of each seedling from the trays, resulting in increased time to complete the pulse. This task was usually done prior to the primary task of transplanting, often utilizing the whole crew. A few farms used soil blocks, requiring less labor during the transplanting activities, but noted to be labor-intensive to prepare at the initial seeding. Some farmers incorporated fertilizer application as part of transplanting activities, either in the waterwheel transplanter (*n*=4) or by hand (*n*=5) into dibbled holes created for the transplants. Crew sizes ranged across crops and were generally greater for the mechanized processes.

Across all crops, labor productivity for transplanting by nonmechanized labor ranged from 61 to 485 transplants per hour person, with an average value of 176. Average crew size for hand transplanting activities was 3.3 people. Comparing nonmechanized labor productivity averages across all crops, broccoli transplanting was completed with a higher rate of labor productivity (314 transplants hr^{1} person^{-1}), while squash transplanting was completed at a lower labor productivity rate (89 transplants hr^{1} person^{-1}).

Labor productivity for mechanized transplants ranged from 212 to 1108 transplants hr^{1} person^{-1}, with an average value of 526. Average crew size for mechanized transplanting activities was 4.6 people. When comparing mechanized averages across all crops, labor productivity was highest for lettuce transplanting (753 transplants hr^{1} person^{-1}), while broccoli transplanting demonstrated the lowest labor productivity (421 transplants hr^{1} person^{-1}). The carousel transplanter was more efficient than most waterwheel transplanters observed on a per-hour or per–unit area basis, although it was not statistically significant. In the majority of observations, the task of mechanical transplanting required an additional crew member to replant any plants not fully placed into the soil.

Farm size affected the labor productivity of transplanting activities. For lettuce, peppers, and squash, larger farms demonstrated higher labor productivity (878 transplants hr^{1} person^{-1}) than small and medium-sized farms (232 and 164 transplants hr^{1} person^{-1}, respectively). Large farms observed for these crops used mechanized transplanters, while small and medium farms used mostly hand-scale tools. For broccoli, labor productivity for transplanting did not vary across farm sizes.

Of all the variables analyzed, mechanization had the greatest relationship labor productivity for transplanting activities, with significant differences observed in the completion of transplanting tasks for lettuce (p=0.0088) and squash (p=0.0460) on a transplants hr^{1} person^{-1} basis. Labor productivity for lettuce transplanting was significantly correlated with farm size (p=0.0021) and new employees being trained (p=0.0197), with lower numbers of transplants per hour observed on medium-sized farms and those with new trainees present.

Harvest Case Studies

In our initial case studies, labor productivity for carrot harvest was influenced by mechanization, although not significantly at the α=0.05 level (p=0.0519) (Table 5). On a per-person average, harvests using a tractor-driven carrot harvester (654 lbs^{-1} hr^{1} person^{-1}) were more efficient than harvests using either the undercutter (122 lbs^{-1} hr^{1} person^{-1}) or hand tools (e.g., digging forks or shovels) (91 lbs^{-1} hr^{1} person^{-1}). However, while mechanized carrot harvesters did increase labor productivity, they also required larger labor crews, with an average crew size of seven. Labor productivity using the undercutter ranged from 26 to 341 lbs^{-1} hr^{1} person^{-1}, with an average of 122 and a crew size of five. Labor productivity using mechanized carrot harvesters ranged from 449 to 1,279 lbs hr^{1} person^{-1}, with a mean of 816 lbs hr^{1} person^{-1}; the labor required for harvesting carrots differed from farm to farm in terms of division of labor. Farms with distinct divisions of labor (e.g., one person digs and another pulls) generally had higher labor productivity than farms with all crew members performing overlapping tasks.

We observed the use of harvest belts for broccoli and squash at one farm, with their use resulting in variable labor productivity as calculated by overall pounds harvested per hour, and not

Table 5. Harvest Labor Productivity Means Characterized by Mechanization and Farm Size and Effects of Five Variables on Labor Productivity for 10 Certified Organic Diversified Vegetable Farms in Wisconsin for Seasons 2014 and 2015

	Broccoli		Carrots		Lettuce [a]		Peppers		Squash	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
Mechanization										
Hand	162 ± 162	156	91 ± 65	90	171 ± 102	156	75		86 ±65	63
Machine	121		400 ± 439	246	n/a		n/a		105 ±18	105
Farm size										
Small			112 ± 75 b	130	229 ± 107 bc	229	78 ± 33 bc		69 ± 41	51
Medium	179 ± 46	151	93 ± 100 b	56	114 ± 48 c	115	36 ± 17 c		81 ± 57	68
Large	180 ± 88	150	581 ± 486 b	468	219 ± 122 b	194	112 ± 52 b		112 ± 82	81
	<----------				***p* > f**				---------->	
Farm size	n/a		0.0242		0.0640		0.0297		ns	
Mechanization	ns		0.0010		n/a		n/a		ns	
Grower presence	ns		ns		ns		ns		ns	
New employee?	ns		ns		ns		ns		ns	
Worker shares/ Volunteers?	ns		ns		ns		ns		ns	

ns Not significant at the 0.10 probability level
[a] Lettuce harvest measured in heads harvested per hour per person
Numbers in columns followed by different letters were significantly different at p<0.10 according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

significantly different from harvests without the use of this tool (broccoli: 121 lbs^{-1} hr^{1} $person^{-1}$ with the harvest belt and 162 lbs^{-1} hr^{1} $person^{-1}$ without; squash: 105 lbs^{-1} hr^{1} $person^{-1}$ with the harvest belt and 86 lbs^{-1} hr^{1} $person^{-1}$ without).

Farm size was correlated with increased labor productivity at harvest for carrots, lettuce, and peppers, but not for broccoli or squash (Table 5). Overall, large farms had higher labor productivity than small and medium-sized farms, but this was not always significant for every crop measured. For carrot harvests, large farms had significantly higher labor productivity than small and medium farms (p=0.0242). For lettuce harvests, large farm harvests had significantly higher labor productivity than medium farm harvests at α=0.10, but not α=0.05 (p=0.0640). For pepper harvests, large farms had significantly higher labor productivity than medium farms (p=0.0297). Grower presence, new employee presence, and worker share presence had no significant impacts on harvest activities across all crops. Overall, harvest activities varied less by mechanization intensity and more by strategies concerning division of labor and process management.

Postharvest Case Studies

Time and technique case studies for postharvest activities were limited to the observation of washing and packing, and tasks within those activities (Table 6). Productivity of brush washer use was measured for peppers and squash, and barrel washer use for carrots. Washing and packing of broccoli and lettuce mostly involved dunk tanks or evaporative pre-cooling. Aside from the brush washing, squash postharvest washing and packing was often minimal.

Across all crops, labor productivity for hand labor postharvest activities ranged from 18 to 58 lbs washed and packed hr^{1} $person^{-1}$ (Table 6). Crew size averaged two people for all processes, whether performed by hand or machine. Labor productivity for mechanized postharvest tasks, using either a brush washer or barrel washer, ranged from 81 to 1,350 lbs washed and packed hr^{1} $person^{-1}$. For activities involving brush washers, labor

Table 6. Postharvest (Washing and Packing) Labor Productivity Means Characterized by Mechanization and Farm Size and Effects of Five Variables on Labor Productivity for 10 Certified Organic Diversified Vegetable Farms in Wisconsin for Seasons 2014 and 2015

	Broccoli		Carrots		Lettuce [a]		Peppers		Squash		CSA [b]	
	<— Pounds washed and packed per hour per person —>											
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
Mechanization												
Hand	212 ± 127	164	158 ± 124	158	n/a		198 ±170	136	187 ± 130	155	30 ± 11	30
Machine	n/a		387 ± 280	304			439 ± 532	150	278 ± 202	277	n/a	
Farm size												
Small	n/a		306 ± 115	283	99	99	296 ± 278	312	216 ± 137cd	193	37 ±6d	36
Medium	189 ± 113	160	210 ± 276	81	65 ± 27d	58	141 ± 100	110	119 ± 54d	127	31 ± 13cd	26
Large	396	396	271 ± 276	134	471 ± 199c	571	520 ± 576	312	417 ± 3c	418	24 ± 9b	25
	<— *p* > f —>											
Farm size	n/a		ns		0.0002		ns		0.0082		0.0900	
Mechanization	n/a		0.0030		n/a		ns		ns		n/a	
Grower presence	ns		ns		ns		ns		ns		ns	
New employee?	ns		0.0830		0.0152		ns		ns		ns	
Worker shares/ Volunteers?	ns		0.0325		ns		ns		ns		0.0924	

ns Not significant at the 0.10 probability level
[a] Lettuce postharvest measured in heads packed per hour per person
[b] CSA box packing measured in boxes packed per hour per person
Numbers in columns followed by different letters were significantly different at p<0.10 according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

productivity ranged from 108 to 1,350 lbs washed and packed hr^{1} person^{-1}, with a mean of 439 lbs washed and packed hr^{1} person^{-1} for peppers and 277 lbs washed and packed hr^{1} person^{-1} for squash. With barrel washers for carrots, labor productivity for postharvest activities ranged from 81 to 883 lbs washed and packed hr^{1} person^{-1}, with an average of 387.

Several variables affected the productivity of postharvest activities. Integration of mechanized techniques into carrot, pepper, and squash postharvest activities trended toward higher labor productivity as compared to hand-washing and packing (387, 439, and 278 vs. 158, 198, and 187 lbs washed and packed hr^{1} person^{-1}, respectively), although only this trend was only significant for carrot (p=0.0002). Barrel washing of carrots (387 lbs washed and packed hr^{1} person^{-1}) and brush washing of peppers (439 lbs washed and packed hr^{1} person^{-1}) and squash (277 lbs washed and packed hr^{1} person^{-1}) had higher labor productivity for washing and packing activities, although not statistically significant in the case of brush washing.

The larger farms in our study group generally demonstrated higher labor productivity for postharvest washing and packing activities, with the exception of carrots. For lettuce, larger farms demonstrated significantly higher labor productivity than medium farms (p=0.0002). For squash, large farms had significantly higher labor productivity than medium farms, but not small farms (p=0.0082). For broccoli, greater measured labor productivity for large farms was found at an overall pounds washed and packed per-hour level (793 lbs washed and packed hr^{1} person^{-1}), but not on a per-person level (397 lbs washed and packed hr^{1} person^{-1}).

Crew experience resulted in significant differences with respect to labor productivity in postharvest events for only one crop. New employee presence significantly lowered the labor productivity for lettuce postharvest activities (61 lbs washed and packed hr^{1} person^{-1} if new employee present versus 327 heads washed and packed hr^{1} person^{-1} if not; p=0.0152). Worker share presence also lowered the labor productivity for complete lettuce postharvest activities (76 heads washed and packed hr^{1} person^{-1} if worker share present versus 249 heads washed and packed hr^{1} person^{-1} if not), although not significantly so. Grower presence had no significant effect on labor productivity for postharvest activities for any of the crops and/or activities measured in this study.

CSA Box Pack Case Studies

Of all the observed activities, case study observations focused on packing CSA share boxes demonstrated the least amount of variation across farms. Average and median number of items packed per CSA was 11 items, with a minimum of 7 and a maximum of 14 and standard deviation of 1.6. No significant differences were observed in the number of boxes packed per hour per person between the different ranges of items packed per box that were analyzed (>10, 10–12, and 13+ items). All farms' CSA box packing was nonmechanized. Variation existed with respect to division of labor (e.g., assignment of tasks to specific individuals) and crew composition. The majority of farms assigned each person on the pack line three produce items to place in each box, with other individuals additionally assigned to prepare and close the boxes. Individuals on the pack line pushed the boxes forward on a roller table, with each person packing their assigned items into the box. A few farms, with smaller crew sizes and fewer CSA members, had one or two crew members packing the boxes, filling each box with every share item before moving on to the next box. Many farms used worker-shares to pack CSA boxes, as training requirements were minimal. The number of boxes packed hr^{1} person^{-1} ranged from 9 to 52.0, and averaged 29.7 across all farms; the average crew size was six for CSA box packs.

Worker share presence and farm size affected labor productivity for CSA box packing at the α=0.10 level, but not at the α=0.05 level. The presence of worker shares increased labor productivity, in number of boxes packed hr^{1} person^{-1} (34.3 boxes packed hr^{1} person^{-1} with worker shares versus 26.2 boxes packed hr^{1} person^{-1} without; p=0.0924). In terms of farm size, the small farms on average had higher labor productivity (36.5 boxes packed hr^{1} person^{-1}) than large and medium farms (23.8 and 30.6 boxes packed hr^{1} person^{-1}, respectively) (p= 0.0899).

Discussion

The short-term objective of this case study of 10 diversified vegetable farms was to assess labor productivity on diversified vegetable farms using the approach of time and technique observations, with the aim of providing an initial understanding of differences in labor productivity as related to production, harvest, and packing practices, as well as farm size. Ultimately, the longer-term goal of this project was to provide benchmark values that can be used to assess the adoption of innovation related to best management practices, mechanization purchases, and scaling up decisions for farms. In the process of meeting this goal, we utilized a novel methodology that provides a framework for food systems and agricultural professionals, as well as farmers and other collaborators, to collect refined, accurate data in their own communities and on their own farms.

Our case studies demonstrate a high level of variability in labor productivity across the crops and activities observed on diversified vegetable farms, reflecting the heterogeneity of approaches to production and management, both within and across farm size classification and level of mechanization. This degree of variability was similar to that found in LeRoux et al. (2010), who concluded that accurate farm financial assessments of small-scale farms needed to be done on a per-farm basis versus using more generalized enterprise budgets in order to properly account for the vast differences in sales, labor requirements, and other associated costs. Our data also support the conclusions of Conner and Rangarajan (2009), who noted large differences in the enterprise budgets generated by land-grant university research programs versus budgets based on actual farm data from organic diversified vegetable farms, resulting from the complexity of the operations and the smaller scale of production of each individual crop.

Time and technique studies proved challenging to implement to the extent needed to collect the number of data points needed across a representative set of farms to appropriately account for the wide range of variability that was observed. While time and technique assessments present a unique approach to estimating labor productivity, they are not without limitations when employed on working diversified vegetable farms. Due to the complexity of data collection and the on-farm, participatory approach employed by the research team, a relatively small number of data points were included in the analyses for each activity performed in each analysis category (farm size, level of mechanization). With a high degree of heterogeneity in farm production approaches, employee management, and environmental conditions, a concurrent high degree of variability in the data was observed, warranting caution when extrapolating from our limited data set more definitive influences of any one or combination of factors on farm labor productivity. As such, the data collecting through this preliminary exercise is best viewed in the context of a comparative case study, rather than an extensive survey of a larger population of diversified vegetable farms in the upper Midwestern U.S.

With respect to recommendations to other agricultural and food system professionals wanting to expand on this work, we can make several recommendations. First, to reduce heterogeneity across all possible farm variables, farms to be included in the study could be selected for increased standardization across certain variables (e.g., crew size, markets, managerial approaches, CSA box share size, etc.). Second, a more limited set of activities and crops may be necessary to achieve the larger sample size needed to account for the high degree of variability of labor inputs and approaches characteristic of diversified vegetable farms. A more limited set of activities would also mitigate the need for the degree of labor employed in the data collection efforts for this study. Ideally, with a stronger emphasis on a crowd-sourcing data approach, data collection would be conducted on-farm by a farm employee. Several farms organized under a specific umbrella group (e.g., a food hub, produce auction, or local National Farmers Union organization, among others) could identify a specific crop and related activities on which to focus data collection for a season, developing a dataset to serve as the basis for benchmark values while limiting the number of hours an employee needed to devote to data collection activities.

While our case study–based analysis is limited to five crops, the results are a starting point to allow farmers, farm advisors, and food system planners to evaluate labor productivity and production costs on farms. However, it must be stressed that, due to the intensity of labor required to conduct this initial trial of time and technique data collection (i.e., two full-time seasonal university employees over the course of two production seasons), the number of observations for each activity and each crop was limited. The ability to make conclusive observations is further confounded in our comparative case study, as we observed high variability in labor productivity across farms despite the deliberate selection of activities that were anticipated to provide relative uniformity across farms. In part, this high degree of variability in productivity emerged due to different approaches for using tools designed to increase productivity (e.g., a barrel washer used in carrot postharvest activities), including the associated division of labor related to the tool varying widely. Additionally, other activities important to managing of and contributing to the labor needs for diversified vegetable farms were not included in our case studies, such as weed management; these activities were deliberately omitted from our efforts as they are strongly affected by both management and environmental factors, thus creating an even greater degree of variability across farms. As such, the creation of benchmark values for these activities becomes even more challenging.

In our limited data set, farm size was correlated with increased labor productivity across several crops and activities; transplanting for lettuce; harvesting for carrots, lettuce, peppers; postharvest for lettuce and squash; and CSA box-packing were all influenced by farm size. Harvest activities are most markedly correlated with farm size, with increases in labor productivity for large farms up to threefold for peppers, lettuce, and squash. Similar gains in labor efficiencies with increasing farm size have been found with other sectors of agriculture in Wisconsin (Bewley, Palmer, & Jackson-Smith, 2001). Higher labor productivity for carrot harvest on large farms is partially explained by the presence of machine carrot harvesters. Overall, larger farms were generally more systematized in their managerial approaches to their labor pools for harvesting, which could account for a portion of the higher labor productivity observed on larger farms. Labor productivity observed for postharvest washing and packing on large farms may be more related to economies of scale; processes creating greater efficiencies may be limited to larger volumes of produce.

In our study, this pattern of lower labor productivity on midsized farms was most pronounced in harvest activities, for all crops except squash. Some of this is attributable to one of the medium farms' focus on education and recruitment of a large pool of "interns." Other speculations on the source of this decrease in productivity suggest that medium farms are scaling up from an operation primarily run and staffed by the farmer(s) themselves, to an operation where a multiperson crew is necessary. This shift requires management skills, which take time to attain, and a change in processes to accommodate a crew. The impact of this shift to larger scales of production, and the associated challenge of gaining the appropriate managerial skills, has been noted in other agricultural sectors (Bitsch, Harsh, & Mugera, 2003). Through focus group discussion, Bitsch et al. found that with increasing farm size, labor becomes an increasingly critical resource; however, with new responsibilities as human resource managers, farmers must also require new skills, which takes time and training. Also noteworthy is the dearth of federal programs and resources for farmers who are no longer considered "beginning farmers" (by the USDA definition), but still need to build skills and receive continuing education as the needs of their operations evolve.

This work also highlights several important aspects of technology and innovation adoption on the production costs for diversified vegetable farms, which could affect the success of farmers to scale up to meet the product demands of our local and regional food systems. Our case studies demonstrate the potential impacts of both bulky and divisible innovations on the productivity of diversified vegetable farms. As described in a report by the National Research Council (2002), bulky innovations can be described most often by those technological advances and innovations that include farm machinery, such as tractors and harvesting equipment, and which require a significant up-front initial investment cost. Conversely, divisible innovations, can be divided into smaller units, theoretically, allowing their adoption to be more scale-neutral. Examples of divisible innovations include the use of new crop varieties and pest management inputs, as well as managerial innovations such as new techniques for weeding or the modification of timing of activities (National Research Council, 2002).

In terms of appropriate technology adoption, certain innovations may be biased toward certain farm scales and management approaches. Bulky innovations tend to be biased toward larger farms with more up-front resources to invest in equipment purchases. Among the variables examined in our case studies, the adoption of bulky innovations (e.g., mechanization) were associated with gains in productivity and productivity of several crops and activities. The adoption of divisible innovations, despite the lack of need for capital funds, may still require a large initial investment, the nature of which potentially biases them toward certain farms (Feder & O'Mara, 1981). Examples of initial investments for divisible innovations include training of employees, which can be a resource drain for small farms who often have managers taking on multiple farm roles. Additionally, as observed in the implementation of our labor resource–intensive time and technique measurements, the on-farm evaluation of new labor, practice, and equipment innovations is a time-consuming endeavor, again potentially placing smaller farms at a disadvantage.

While both bulky and diffusive innovations can provide benefits to the productivity and profitability of farms of all scales, in order to account for the potential economic disadvantages of innovation adoption that can biased toward small farms, it is crucial to ground Extension and outreach efforts focused on innovation within the context of appropriate technology adoption. It is recognized that technical change, including that arising from agricultural research and development, is a key driver of both profitability and productivity (Mugera, Langemeier, & Ojede, 2016). However, in tandem with research efforts to enhance the productivity and profitability of vegetable farms, Extension and outreach efforts must be conducted to facilitate the adoption of both new and existing technologies, to ensure that beneficial advances occur on-farm (Schimmelpfennig, O'Donnell, & Norton, 2006).

While this initial comparative case study does not include an adequate number of data points to provide conclusive explanations, it does begin to elucidate the appropriateness of both bulky and divisible innovations across various scales of diversified vegetable farms, due to observations indicating higher labor productivity on large farms as compared to small and medium farms. Although our observations are preliminary and qualitative, it appears that these gains in labor productivity are a combination of bulky innovation (e.g., greater use of mechanized equipment) and divisible innovation (e.g., how labor crews are using the equipment). As medium-sized farms begin to invest in mechanization to achieve the efficiencies of the larger farms in our study group, overall economic advantages may not be realized, as the gains in greater labor productivity may not offset the high cost of equipment; thus efforts to incorporate more mechanization may be unprofitable, depending on the specific techniques with which the equipment is used.

While the relationships between farm scale and mechanization are correlative and are not absolute across all crops and activities, they cannot predict labor productivity. Yet they point to what sets some farms apart with respect to productivity, and indicate crops or activities that can benefit from adoption of machinery or are more suitable for scaling up production. Information such as that presented in this paper, gained from time and technique studies, could help farmers make more strategic decisions—with regard to both machinery purchases and crop specialization—that could better position them to supply greater volumes of produce to wholesale distributors or food hubs serving local and regional markets, while still remaining price-competitive and profitable. Lack of knowledge and information about the costs and benefits of adopting new technologies or conservation practices significantly affect a farmer's propensity to utilize these technologies (Bowman & Zilberman, 2013), thus highlighting the importance of quantifying technological advantages to incentivize farmers.

Other considerations such as crew size, farm land base, and worker welfare are also important elements in assessing the advantages of each mechanized process. In our study, mechanization resulted in significantly higher labor productivity for all transplanting activities, carrot harvest, and postharvest activities. Transplanting by hand is very labor-intensive across all crops, and mechanized transplanting has the potential to increase labor productivity up to tenfold. Crew size remains a critical consideration, however, as mechanized transplanters require an average of four to five crew members. As a result, farms with fewer crew members may not be able to support the use of mechanized equipment, such as a waterwheel or carousel transplanter. Logistical concerns about space and turning radii must also be factored into decisions about mechanization. Activities for which the mechanized process did not show significantly higher labor productivity as compared to the nonmechanized process were usually attributable to a major difference in crew size or inexperience with equipment.

Worker welfare emerged as a factor entering into mechanization decisions as well. This balance between cost-benefits and welfare considerations is illustrated by the example of harvest belts. With the use of this mechanized equipment, the average crew size needed for harvest was relatively large, with 8.3 people designated to a specific harvest task, which decreased the labor productivity (calculated per person) and crew available to complete other tasks. But some additional equipment, such as harvest belts, can incorporate ergonomic and worker welfare benefits, adding to the advantages of these machines. Other types of equipment offered benefits with respect to both ergonomics and productivity; for example, barrel washers greatly increased labor productivity without requiring an increase in crew size. Many farmers praised the benefits of a barrel washer, rather than washing vegetables by hand, a time-consuming and uncomfortable task. As such, within this study, barrel washers emerged as one of the mechanized tools more flexible regarding farm scale.

The data collected in this study also speak to the capital/labor dynamic central to economic analysis, illustrating deviation from a simple fixed ratio where more capital translates to less labor needed to complete a task (Shapiro, 1986). Tractor-pulled transplanters and carrot harvesters are effective, but their crew size requirements render them less widely adaptable on diversified vegetable farms. With crew sizes smaller than five, the barrel washer for carrots is the only scale-appropriate machine that had significant effects on labor productivity observed in this study. The dichotomy in the factors driving mechanization decisions on the small and medium-sized farms underlines for the need for scale-appropriate, inexpensive machinery.

Despite limitations, the study does achieve its initial objective of preliminarily assessing labor productivity on diversified vegetable farms using the novel approach of time and technique studies, allowing for an initial evaluation of the impact of farm size, level of mechanization, and employee management on labor efficiencies, and ultimately, farm profitability. With this data as guidance, future research and extension directions for food system and agricultural professionals can better be determined.

Conclusions

Despite this comparative case study's limitations and small sample size, it illustrates the potential value of time and technique studies to assess labor productivity and cost of production on diversified vegetable farms. More extensive studies, with the inclusion of a greater number of farms, could broaden this set of case studies and provide additional data to further decipher the interactions of labor management, mechanization, and labor productivity, particularly as related to scaling up to serve regional food systems. Time and technique studies could also contribute to collective resources and tools for regional sustainable agriculture organizations and professionals involved in supporting local and regional food systems. One possible resource includes the compilation of results and insights from case studies that growers could use to better evaluate the impact or pay-back time of investing in a tool such as a transplanter or root washer. Through the completion of this project, we aimed to provide farmers and collaborating food systems development specialists with data and tools to assess farm economic status, contributing to the body of work to assist farmers in balancing various constraints, such as crop diversification, labor inputs, and marketing channels (Navarrete et al., 2015). Further, this information can inform strategies and policies to aid small and midscale diversified farmers in the scaling-up of regional food systems, such as mechanization adoption. While some of the information outlined in this paper can be directly integrated into farmer decision-making—such as altering crew management, increasing or decreasing production areas depending on the labor inputs required for crops, or rethinking postharvest and pack shed configurations—other aspects can direct efforts of Extension educators, food system development professionals, nonprofit organizations, and food hub managers.

It is critical to recognize that, with any promotion of technology, the technological change must be scale- and cost-appropriate for a farm's financial, labor, and physical resources. A change in mechanization often requires a financial investment for farmer; thus, the farmer must achieve greater production or increased value of the product in order to increase profits and justify the cost of the technology (Food and Agriculture Organization of the United Nations [FAO], 2007). Further, as described by Just and Zilberman (1988), if small farms cannot adopt a new technology that is readily available to their larger counterparts, the small farms can suffer further economically if the new technology leads to industrywide reductions in prices.

While midscale farms may lack immediate access to capital for the purchase of bulky innovations, policies and business models that promote cooperative ownership or lease agreements could have benefits for farmers scaling up to a midsize production model. For example, equipment lending and leasing programs could be organized by Extension agents, cooperatives, and state agencies or nonprofits. While short-term leasing and contracting of equipment is common in row crop and grain production, the practice remains relatively uncommon in vegetable cropping systems. Alternatively, while not a new concept, farmers with moderate equipment needs and smaller acreage might development agreements to share equipment, in arrangements that could include farms in close and more distant geographic proximity (Artz, Colson, & Ginder, 2010; Ginder, Artz, & Colson, 2004). This strategy can also benefit postharvest operations, through coordination of shared packing and storage facilities when crop production portfolios are complementary. In areas with a high density of small and midsized vegetable farms, equipment sharing may take the alternative form of a custom operator, offering an alternative income stream for some farmers. While larger farms tend to be early adopters with respect to bulky innovations (Feder, Just, & Zilberman, 1985; Marra & Carlson, 1990), this bias might be reduced if cooperative equipment sharing models were expanded.

Additionally, policies could support research and business endeavors that develop tools for midscale vegetable farms and incentive programs to make these tools more affordable. Such programs could include low-interest loan programs, such as the programs administered by the USDA Farm Service Agency to assist small and midscale vegetable producers build postharvest storage capacity (USDA, 2016a) and finance their agricultural operations (USDA, 2016b). With promotion of both technical and policy support, farmers, policy-makers, program activists, and food systems professionals can strengthen synergies between production approaches, labor management, and market decisions, thereby improving the performance of farms serving local and regional food systems.

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