State of Indoor Farming

September 2016

agrilyst

About the Authors

Agrilyst is a management and analytics platform for indoor farms. The SaaS platform tracks and analyzes all farm data in one place, enabling growers to optimize plant performance and reduce operating expenses. Agrilyst is focused on turning data management from a burden into a grower's most useful tool.

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Acknowledgments

We would like to thank the following people for their input and contributions to this report: Chris Higgins, Urban Ag News, Henry Gordon-Smith, Kerstin Schreiber, Andrew Blume, the Association for Vertical Farming, Aaron Grosbard, David Ross, FarmersWeb, Dr. Neil Mattson, Wylie Goodman, Cornell University, Thomas Hallaran, Laura Seach, Foodshed.io, Paul Brentlinger, CropKing, Jason Green, Edenworks, Daniel Christensen, Strata Farms, Thanos Papanikolaou, Phos Gourmet, Nick Burton, Paris Victory Gardens, James Brady, Con10u2farm L3C, Rich Andrews, Neutech, Jessica Vaughan, Jacobs Farm Del Cabo, Inc., Carlos Williams, StudioDBC, Meghan Keane Graham, Brick Wall Media, Shanrah Wakefield , Jordan Koschei, and Karen Krieb.

Introduction

The purpose of this report is to look at the emerging trends, challenges, and benefits of farming indoors. There are many unknowns and misconceptions about the indoor farming market. We wanted to provide detailed insight into what indoor growers are doing, what they're challenged by, and how they see the indoor farming industry changing over the next few years. So, we teamed up with Cornell University, Urban Ag News, foodshed.io, the Association for Vertical Farming, and FarmersWeb to survey growers from around the world, receiving over 150 responses. Seven participants also offered to be interviewed further, offering additional insight. Interview summaries are included in this report. Data from the survey is supplemented by research conducted by our team and others (as cited).

Our Partners

1 The Landscape

The crops and facilities that make up the indoor farming industry.

Indoor agriculture is one of the fastest growing industries in the United States. As the world's population continues to rise, so does the importance of building secure and consistent food supplies. The amounts of available arable land and water to support conventional agriculture are dwindling. While conventional agriculture is locationally tied to areas with sufficient land and water, indoor farming is decoupled from such needs and can be located closer to the point of end consumption.

Types of Facilities

Aeroponic Greenhouse
translucent, climate controllable structure where plant roots are suspended in the air and misted with a nutrient solution

Aquaponic Greenhouse
translucent, climate controllable structure where plants are grown in water that has been used to cultivate aquatic organisms (typically, fish)

Container Farm
standardized, self-contained growing unit that employs vertical farming systems and artificial lighting.

Hydroponic Greenhouse
translucent, climate controllable structure where plants are grown in water as opposed to soil

Indoor Vertical Farm
fully enclosed and opaque room with a vertical hydroponic, aeroponic, and/or aquaponic system. Artificial lights are used.

Soil-based Greenhouse
translucent, climate controllable structure where plants are grown in soil

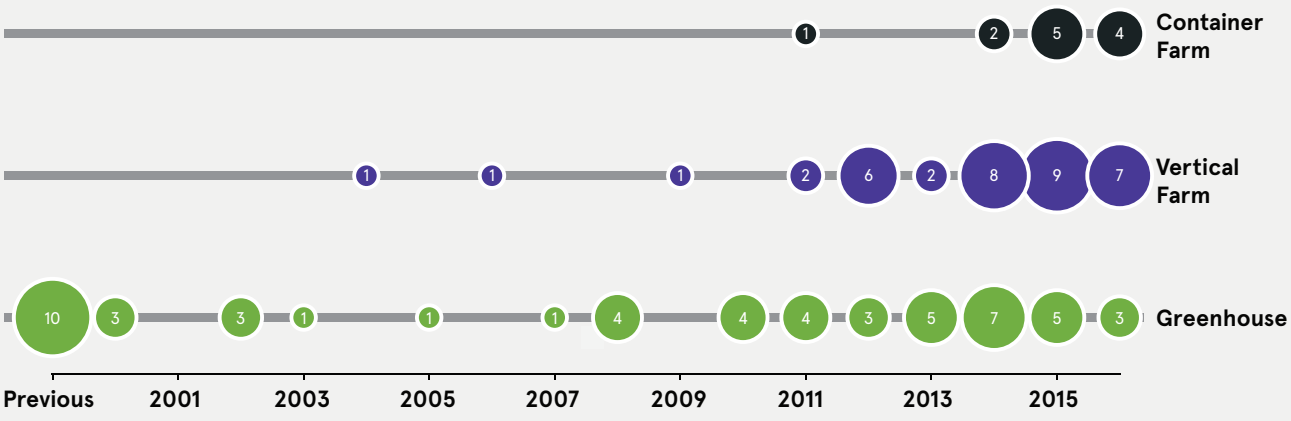
In Home Systems
small standardized growing unit for use by consumers in home settings.

As the growing population continues to grow and urbanize, farmers are opening up indoor facilities closer to these urban areas creating a local, stable, and sustainable year round food supply. Indoor agriculture isn't only urban farming however. It can take many shapes and forms, from8 urban and small space farming, to high-tech fully controlled and semi-automated greenhouse facilities in rural areas, to everything in between.

By enclosing farms, indoor growers can use technology to control farm inputs and to create artificial environments within their facilities. Increased control allows for a higher degree of precision and also allows growers a wider range of crop selection.

The indoor farming industry in the United States was predominantly dominated by greenhouse crop production until about 10 years ago. During that period, an increasing number of vertical farms and more technologically advanced greenhouses emerged, primarily due to the decrease in technology costs and an increase in local demand for food. Nick Burton, the owner of Paris Victory Gardens in Texas, believes the cost decrease in LEDs will lead to a large investment from growers in the technology, leading to an equal T5[1] to LED market share in the next 10 years. Burton also credits the industry's current and future growth to the local food movement, saying "we're far from peak on local food, value-added sales will continue to increase, and a merging with the culinary field will happen."

Timeline of farm openings



1 — T5 lights are a type of fluorescent lamp.

"Urban agriculture is just now coming into its own. We haven't even scratched the surface yet."

James Brady
Founder, Con10u2farm L3C

Indoor vertical farms and hydroponic greenhouses were the most prominent primary facility type of survey respondents. All farms were placed into one of two size categories: large farms (> 1,500 square feet), and small farms (< =1,500 square feet) based on observed consistencies in the data. Small farms primarily consisted of indoor vertical farms while larger farms primarily consisted of hydroponic greenhouses. Indoor vertical farms have stacked growing systems, which allows growers to realize higher revenues and yields in less space than in horizontal facilities. As we examine reported revenue, budget, and labor numbers per square foot, we see a wider range of numbers for small farms primarily as a result of these vertical advantages.

What are indoor farmers growing?

Any crop can be grown indoors. The more common crops grown indoors are greens, microgreens and herbs, vine crops, cannabis, some fruits, and flowers or nursery crops. Survey respondents also reported growing tubers, mushrooms, insects, hops, algae, and commodity crops (corn and wheat).

Survey respondents are growing greens, microgreens, and cannabis in greenhouses, vertical farms, and container farms, while they are growing vine crops and flowers predominantly in greenhouses.

A selection of crops grown indoors

Greens
leafy greens, lettuce, spinach

Hops

Insects

Strawberries

Vine Crops
tomatoes, peppers, cucumbers, eggplants

Flowers
perennials, annuals, ornamentals

Microgreens/ herbs

Vegetable Transplants

Fruits

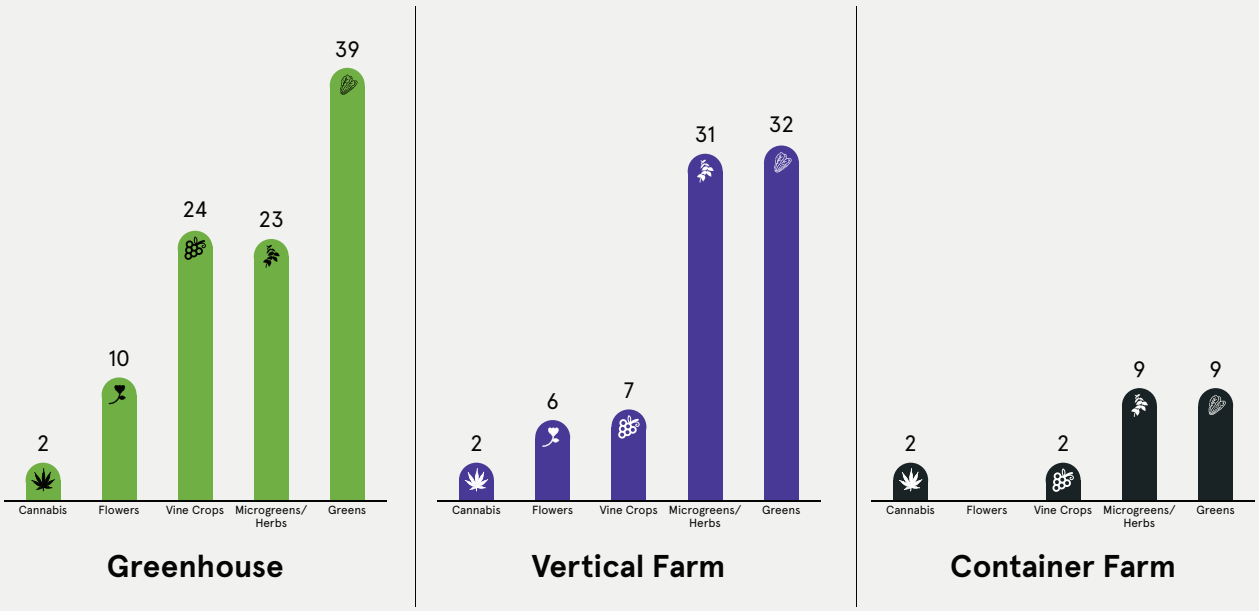
Cannabis

Commodities
corn, wheat

Other
poultry, forestry seedlings, algae

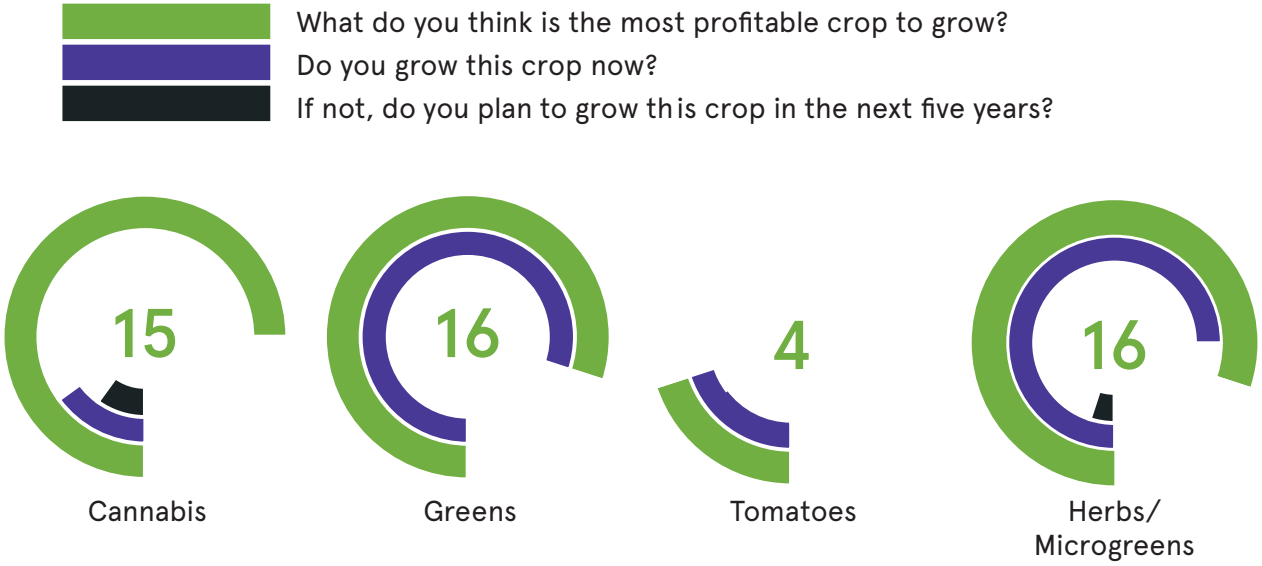
Other Vegetables
tubers, mushrooms

Crops grown by facility



For the most part, indoor farmers believe the products they've chosen to grow are the most profitable and they plan to continue growing those crops in the future. Greens and herbs/microgreens top the list of crops growers believe are most profitable to grow. Though many growers agree that cannabis is the most profitable crop, most do not plan to grow it in the next five years.

Grower expectation of crop profitability



Greens include lettuce, kale, spinach and greens
Herbs/Microgreens include basil, herbs, tarragon and wheatgrass
Other includes food supplements, ethnic foods and flowering plants

With regard to annual production and revenue capacity, cannabis topped the list of highest revenue generating crops at about $112 per square foot or about $4,800,000 per acre. Greens were the next highest revenue generating crop at $64 per square foot or about $2,800,000 per acre. The lowest revenue generating crop reported was strawberries at about $22 per square foot or $1,000,000 per acre.

Increased transparency in actual realized yield and revenue within the industry may help growers choose to grow more profitable crops. However, crop selection is also determined by local markets, distribution channels, and regulation barriers. This will be explored later on.

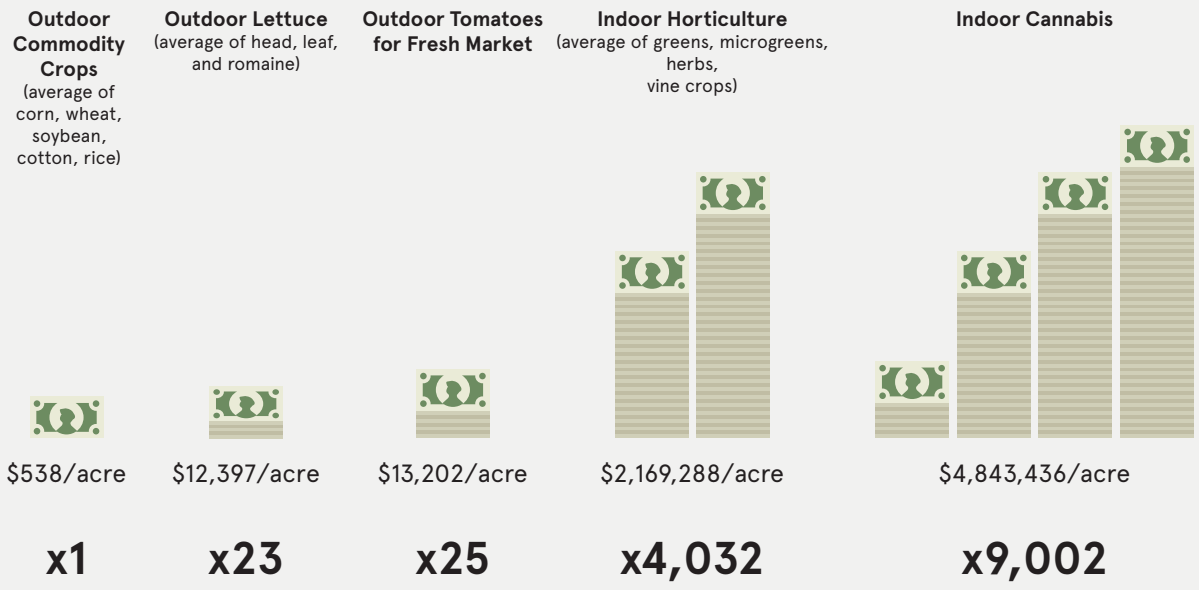
Large Farms >1,500		Small Farms <= 1,500	
Crop	**Average annual revenue ($/sf)**	**Crop**	**Average annual revenue ($/sf)**
Cannabis	$111.90	Cannabis	$36.67
Flowers	$40.03	Flowers	$106.14
Greens	$63.52	Greens	$72.37
Microgreens/ Herbs	$56.30	Microgreens/ Herbs	$66.79
Other	$28.54	Other	$157.12
Vine Crops	$29.58	Vine Crops	$175.09
Strawberries	$21.65		

2 Production & Operations

A snapshot of how indoor farms operate.

One of the reasons indoor farming is gaining significant traction in the United States is the ability to produce more while using less resources. According to the United States Department of Agriculture's (UDSA) July projection for the 2016 - 2017 growing year, corn prices range from $3.10 - $3.70 per bushel and farms are producing an average of 168 bushels per acre[1]; conventional lettuce and tomatoes are between 23 and 25x more productive at about $12,000 and $13,000 per acre respectively. In comparison, on a revenue basis alone, indoor horticulture is about 4,000x more productive than conventional outdoor commodity farming; indoor cannabis is about 9,000x more productive.

Farm productivity



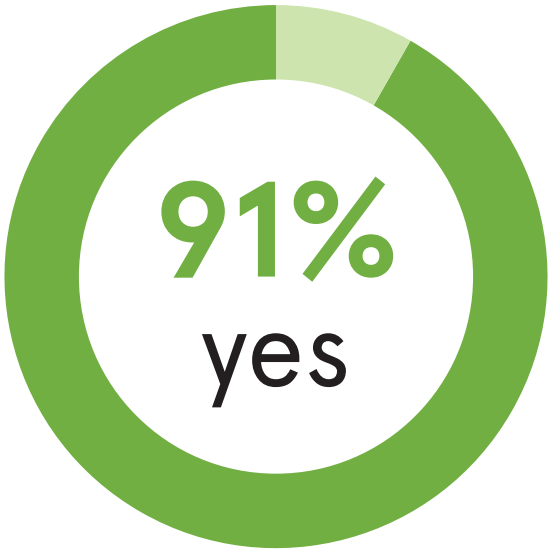
1 — "World Agricultural Supply and Demand Estimates," United States Department of Agriculture, 2016
"Crop Production 2015," United States Department of Agriculture, 2016

The higher revenues realized by indoor farming are driven by three factors: (a) year round production capability, (b) higher yield, and (c) higher retail pricing.

Year Round Production

Having the ability to create ideal and artificial climactic environments within an indoor farm allows growers to extend the growing season of crops and decrease the time it takes to grow a crop from seed to harvest. If cost was immaterial, indoor farms could create perfect growing environments, controlled by technology, year round and produce the most high-yielding crops. Growers cannot ignore cost however, so instead they strive for optimized resource management while producing the highest possible yielding plants in the fastest possible time.

Percentage of indoor farmers who grow year round



The standard growth cycle (planting to harvest) of leaf lettuce planted in California ranges from 65 days in the summer to 130 days in the late-fall to

winter[2]. In a given year, assuming there are no weather-related incidents, outdoor conventional lettuce farmers will be able to harvest their entire farm 4–5 times. In comparison, lettuce can be grown indoors as quickly as 14 or 15[3] days and as long as 35 days[4]. Indoor farmers will be able to harvest their entire farm an average of 18 times in a given year.

Harvest cycles per year

1x Outdoor Lettuce

4x Indoor Lettuce

Yield

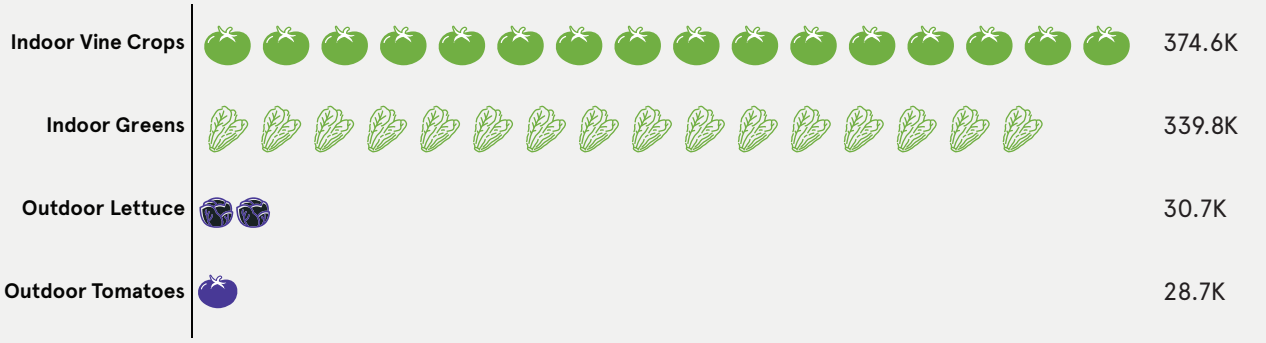
Not only can indoor farmers extend growth seasons for year round production, they are also realizing higher yields by utilizing indoor growing methods. According to the USDA[5], the average yield for outdoor conventional lettuce[6] production in 2015 was about 30,000 pounds per acre. After removing survey outliers, indoor greens growers reported growing an average of 340,000

2 — "Leaf Lettuce Production in California," UC Davis, 2011
3 — "Why Chicago Is Becoming The Country's Urban Farming Capital," FastCo Exist, 2016
4 — Note: This is the growth cycle for head lettuce.
"Hydroponic Lettuce Handbook," Cornell University
5 — "Vegetables Summary," United States Department of Agriculture, 2016
6 — Average of head, leaf, and romaine lettuce.

pounds per acre annually. The 11x increase in yield over conventionally grown lettuce is partially due to faster growth times as detailed above. After removing the benefit from cyclical advantages, the increase due to indoor productivity alone is 2.8x.

Similarly, the average production capacity for outdoor tomato crops in 2015 was 28,700 pounds per acre. Indoor vine crops[7] growers reported growing 375,000 pounds per acre annually, a 13x yield increase when moving production indoors.

Annual production capacity of indoor crops vs. outdoor crops



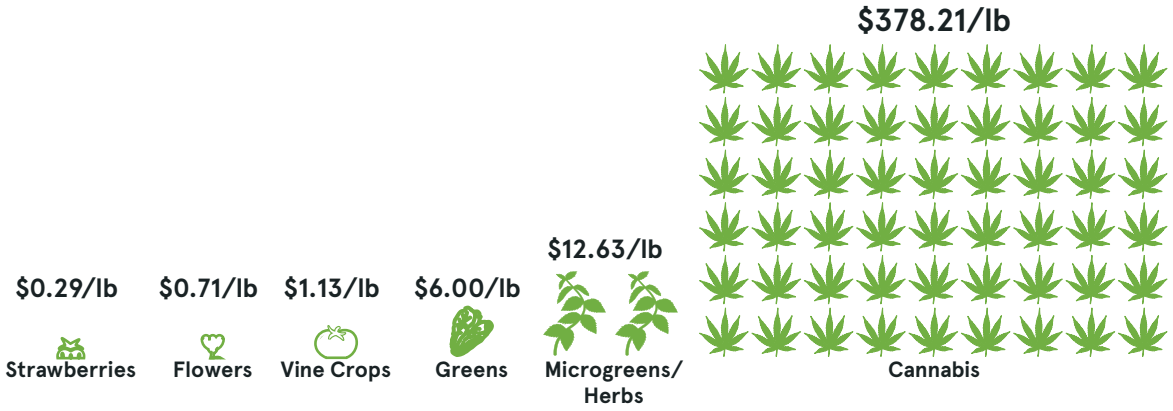
Higher Retail Prices

According to the USDA[8], the average price per pound of conventionally grown head lettuce was $0.29 in 2015. In the same year, the price of leaf lettuce was $0.58, the price of romaine lettuce was $0.39, and the price of tomatoes for the fresh market was $0.46 per pound.

7 — Primarily tomatoes, but also includes averages from peppers and cucumbers.
8 — "Vegetables Summary," United States Department of Agriculture, 2016

In comparison, indoor greens growers reported revenues[9] of $6.00 per pound and indoor vine crops growers reported revenues of $1.13 per pound. Even compared to the highest priced conventional lettuce crops, indoor greens farmers are seeing 10x increases in pricing and indoor tomato growers are seeing 2.5x increases in pricing.

Annual reported revenue by crop



The majority of survey respondents reported selling directly to consumers and restaurants in the retail market. For growers selling to both retail and wholesale markets, 27% are seeing 10–24% higher prices in retail over wholesale markets. Additionally, 22% of growers are seeing price increases as high as 50–100%.

How does this break down?

Consider a farmer cultivating five acres. On two and a half acres the farmer is growing conventional field grown leaf lettuce. On the other two and a half acres the farmer is growing hydroponic leaf lettuce in a greenhouse.

9 — Growers could report growing multiple crops and only reported one revenue number. If a grower reported multiple crops, the revenue numbers are included in both categories of crops.

For the field grown lettuce, the farmer will harvest 4-5 crop turns in a given year, yielding 75,000 pounds of produce. At $0.58 per pound, the farm will generate $43,500 in a year. For the greenhouse portion of the acreage, the farmer will harvest an average of 18 crop turns, yielding 850,000 pounds of produce. At $6.00 per pound, the farm will generate $5,100,000 annually.

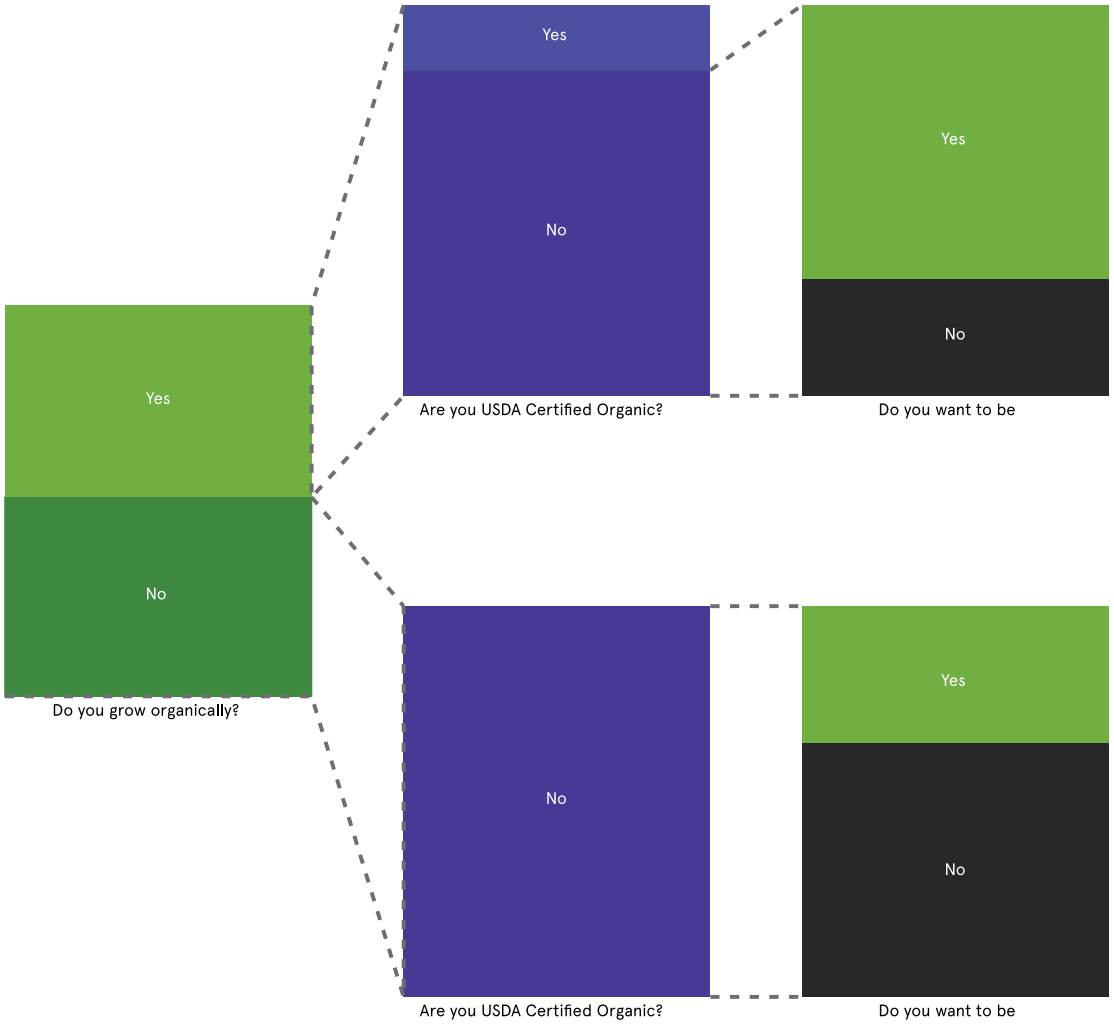
63% of the yield increase is due to an increase in yield productivity from growing indoors. 37% of the yield increase is due to extra crop turns from growing indoors. The biggest revenue driver is the higher retail price at $6.00 per pound, though even at an equivalent $0.58 per pound, the greenhouse production space would still produce 11x revenue as a result of the yield increases.

Organic Certification And Local Production

Half of survey respondents reported growing organically though only 8% of growers answered that they were certified as USDA Organic. When asked if growers who weren't certified wanted to achieve the certification, 47% of growers indicated interest in the certification. Indoor farmers are seeing price increases from factors beyond USDA Organic certification, including a high demand for local food, access to higher-end markets and retailers, consistency of year round local production, and freshness at delivery.

Many growers who are not seeking official organic certification still reported growing organically. One of the requirements for organic certification is the avoidance of synthetic chemical inputs, such as fertilizers and pesticides whenever possible. Of those surveyed, 34% reported utilizing integrated pest management, a process using beneficial insects to eliminate pests and 32% of growers reported growing pesticide-free crops.

Organic Production Snapshot



Pest management isn't the only tenet of USDA Organic certification. There is an ongoing debate on whether or not hydroponic and aquaponic growers will be able to achieve the USDA Organic designation due to the lack of soil involved in production. In July, the National Organic Standards Board Hydroponic and Aquaponic Task Force concluded "that systems of crop

production that eliminate soil from the system, such as hydroponics, cannot be considered as acceptable organic farming practices[10]."

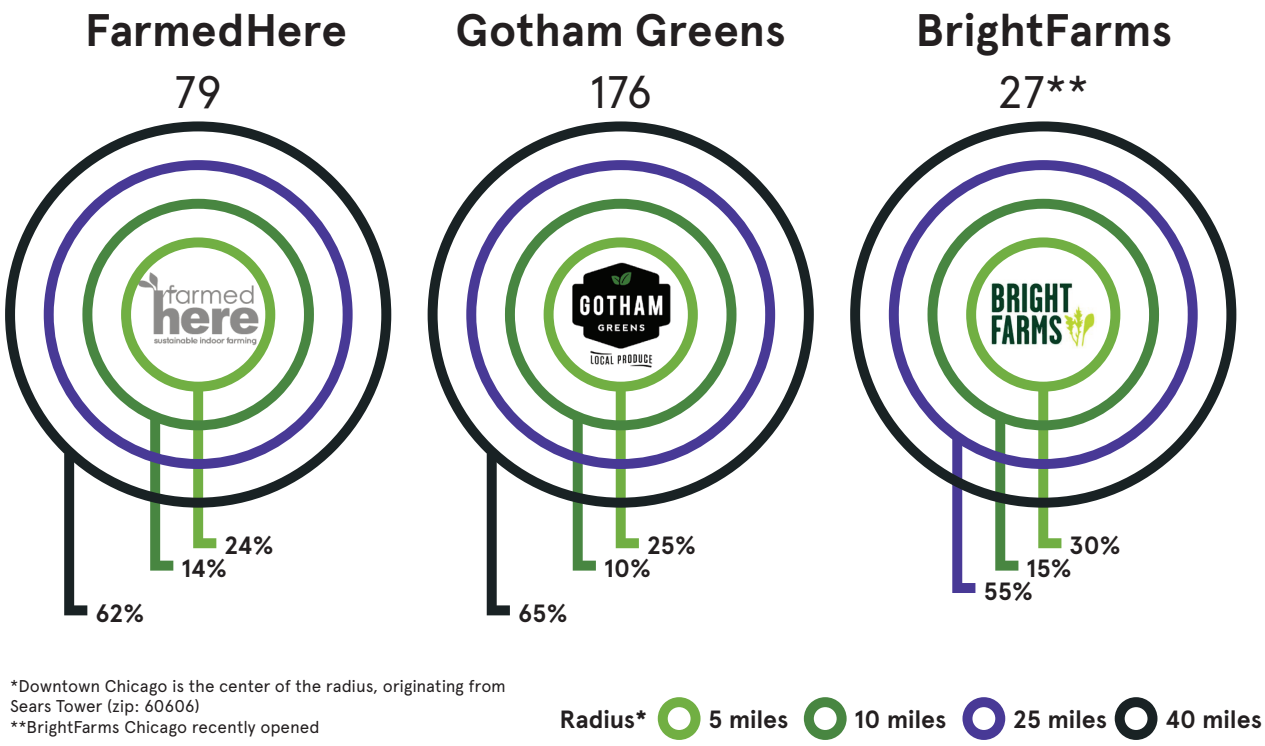
Jessica Vaughan, a hydroponic grower at Jacobs Farm Del Cabo, Inc in California, believes that this pending ruling on USDA Organic certification for hydroponics will dictate the future of the hydroponic agriculture industry. Without the possibility of organic certification, Vaughan posits that "hydroponic farmers may lose the motivation to continue that type of production. Organic hydroponic farming allows growers to push boundaries and be innovative in farming practices, so limiting organic certification to traditional in-ground production techniques means interesting new methodologies and highly efficient techniques could be lost and the clock would be set back on progress that's already been made."

Thanos Papanikolaou, Senior Agronomist and CTO/co-owner of Phos Gourmet farm in Greece, believes "organic certification will play a significant role in the near future, since people are becoming widely aware of the necessity of consuming organic vegetables for obvious health benefits. We believe that prices of organic vegetables will be higher than conventionally cultivated ones."

For some growers, organic certification falls after other priorities such as increasing the efficiency and availability of locally grown food. Jason Green, the CEO and co-founder of Edenworks, is focused on "increasing the efficiency and availability of locally grown food." According to Green, the current food distribution system wasn't built with freshness as a priority - consumers in the United States aren't eating the highest quality greens possible, because produce can spend a week in transit from production

10 — "Memorandum to the National Organic Standards Board," 2016

Chicagoland stores serviced by leading indoor farms



*Downtown Chicago is the center of the radius, originating from Sears Tower (zip: 60606)
**BrightFarms Chicago recently opened

This graphic outlines the proximity to local marketplaces for three industry leaders located in the Chicagoland area. The data was pulled from company websites.

centers in California and Arizona before reaching the grocery store. "Indoor farming changes the freshness game, especially when businesses focus on quality, yield, and cost reduction" said Green.

Though many farms are capitalizing on the local trend and benefits of growing fresher food for regional markets, delivering fresh food to local markets daily presents distribution challenges for smaller urban farms. Daniel Christensen is the owner of Strata Farms, a 420 square foot microgreens vertical farm

located in Portland Oregon. Strata is a family-run operation and their customers include two of the biggest farmers markets in the area, a local grocery store, high-end restaurants, and large offices. For Christensen, distribution to local markets is a daily challenge. Produce must be delivered to all locations in a refrigerated van or in coolers. Christensen believes "the current food distribution chain doesn't fit very well with the shelf life realities of fresh, locally grown produce. Even though you can farm in urban areas, you have the challenge of getting the food that 'last mile' to the consumer."

The Sales Market

A number of farmers interviewed noted the importance of understanding and qualifying a market before beginning operations. Some indoor farming companies are securing contracts with purchasers in advance of constructing farms to address the concern of managing many purchase orders, deliveries, and uncertainty in sales.

About 53% of growers who responded to sales related questions reported that 75–100% of their sales come from repeat orders. Because indoor farmers can forecast yields ahead of time and maintain year round consistency, they are not limited to selling at farmers markets or other small markets. Instead they can also sell to retailers where demand is known ahead of time and farms can match those demands. Access to traditional retail markets means access to a $9b[11] market for indoor food producers.

Operating Costs

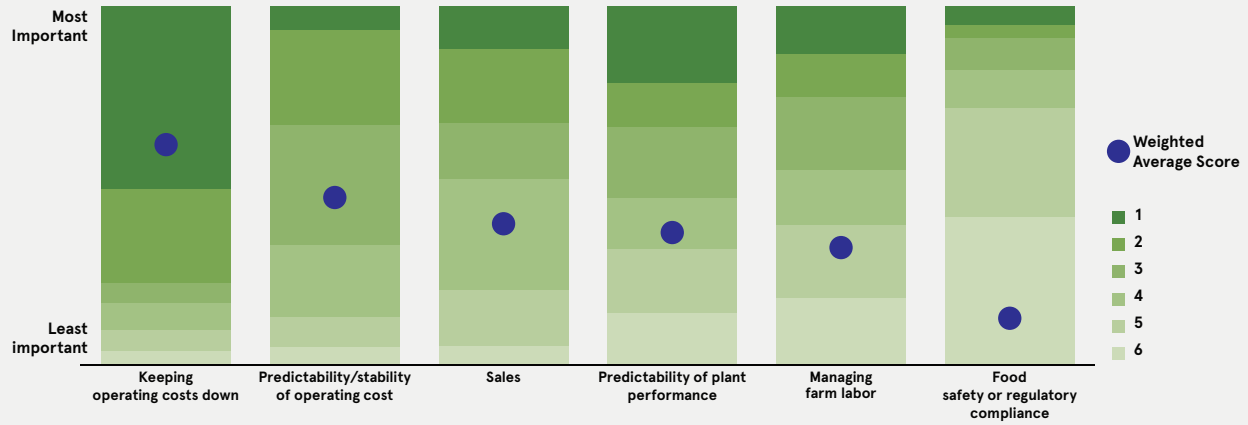
One of the criticisms of indoor farming is the high cost to operate. When asked about their biggest challenges, growers reported managing operating

11 – "Indoor Crop Production Feeding the Future," Newbean Capital and Local Roots, 2015

costs as the most difficult - their highest priorities were both reducing and predicting/stabilizing operating costs.

Labor is one of the most costly components of indoor farming operations. For Papanikolaou, labor comprises 45% of the cost of producing a tomato. Phos

Top ranked operational challenges

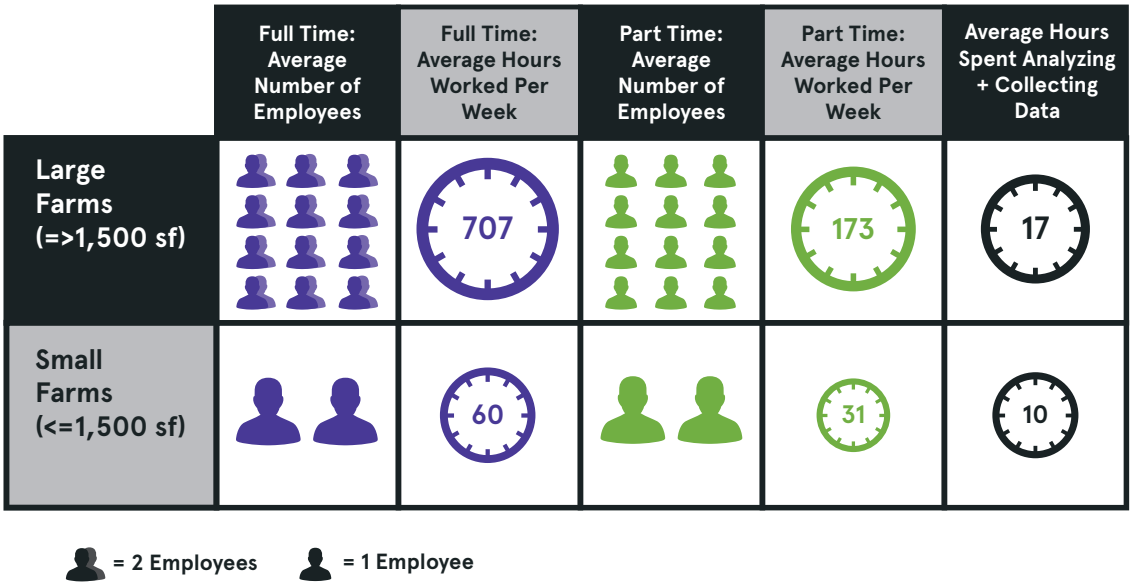


Gourmet employs 40 workers full time on a 2 hectare farm (about 5 acres), at approximately 47 hours per employee per week. Hours vary depending on vegetative stages.

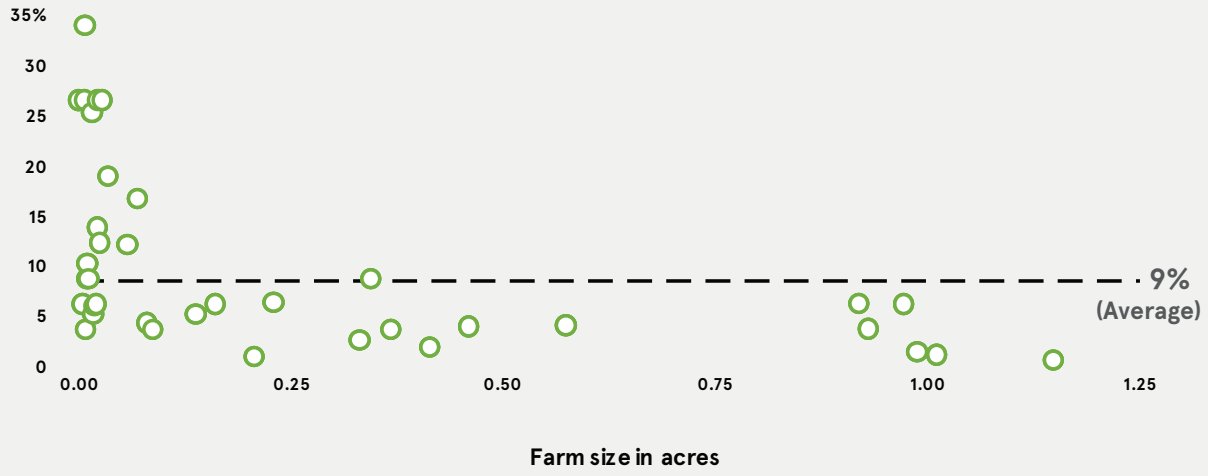
The number of employees needed for farm operations typically scales with the size of the farm. Large farms, like Phos Gourmet, employ an average of 24 full time and 12 part time employees. Small farms reported an average of two full time and two part time employees.

On average, data collection and analysis account for about 9% of a farm workforce's weekly labor hours and 27% of respondents spend 20 or more hours per week on data collection and analysis. Notably, the number of hours

Labor Snapshot



Time (%) spent by farmers collecting and analyzing data

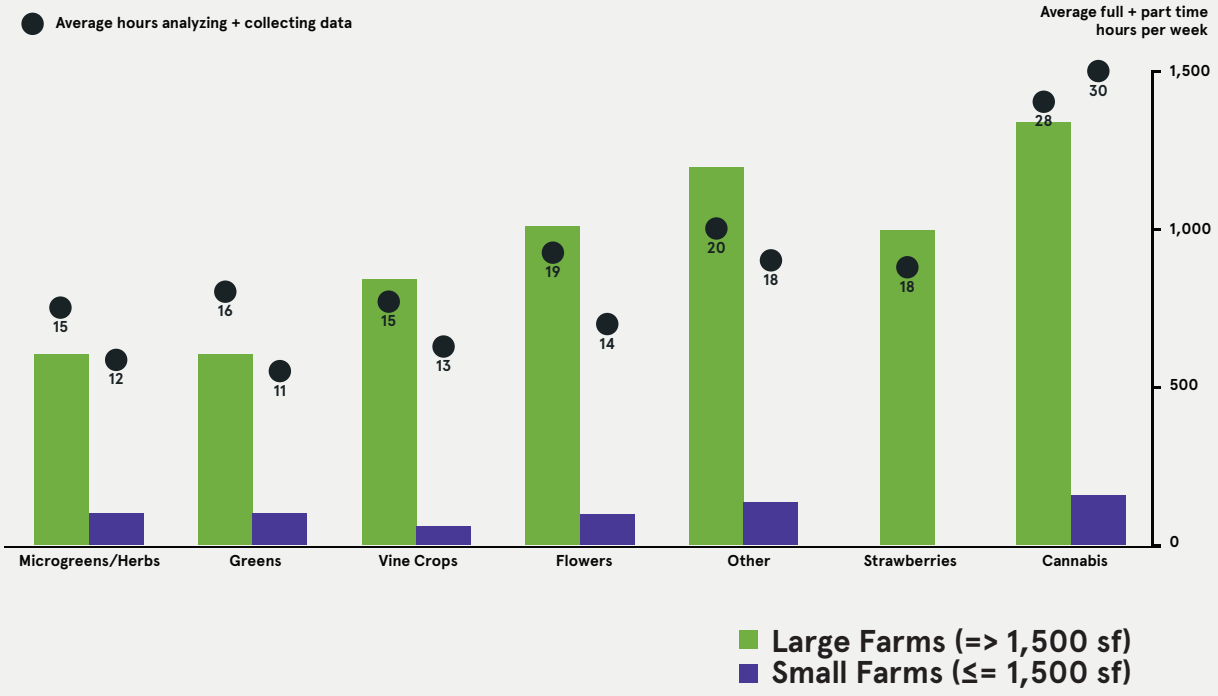


a farm spends with data isn't proportional to size of farm, with small farms spending a proportionally higher percentage of their time working with data.

Small farms can lose out on economies of scale that benefit large scale operations. Processes remain relatively stable from small to large scale production, requiring a higher percentage of labor per square foot for smaller operations.

The results also suggest that younger farms are more data driven than older farms, with a large number of hours per square foot spent collecting and analyzing data. This is a trend that holds true regardless of farm size, meaning newer large farms are comparatively more data driven than older ones. This may be due to recent technology developments in the space as well as a rising awareness of the importance of data for operations.

Average weekly total labor hours and hours spent collecting and analyzing data by crop



General labor needs and time spent on data collection and analysis also depend on which crops are grown by a farm. Cannabis growers, whether small or large, spend the most time working with data (about 30 hours per week on average). Large cannabis growers also have the largest reported workforce, and growers of greens and microgreens/herbs have the smallest, comparatively.

Product processing and packaging costs are another big cost component for farms. Of those who responded to questions about costs, 60% of growers reported dedicating 1–24% of their operating costs to packaging and processing their crops and 27% reported dedicating 25–75% to packaging and processing. 75% of growers reported dedicating 1–24% of their operating costs to marketing and distribution, while another 11% reported dedicating 25–49% to marketing and distribution.

In addition to high operating costs, indoor farms are expensive to build. Greenhouse structures can range in cost from $10 to $20 per square foot based on structure material and type, and another $50 to $100[12] per square foot depending on the growing systems and technology inside of the structure.

Consider the same five acre farm from earlier. For indoor producers to pay back their capital expense in a realistic timeframe, they have to realize a combination of all three revenue influencers (yield, growth time, and pricing). If we roughly assume a capital cost of around $100 per square foot for a higher end greenhouse facility. At two and a half acres, the facility will cost the farmer roughly $11,000,000. To pay back the capital expense within 36

12 — The base model of a Freight Farms Leafy Green Machine, a production unit made from an up-cycled freight container, costs $85,000 to purchase (http://www.freightfarms.com/faq/). BrightFarms Chicago facility cost $10m to build: http://www.chicagotribune.com/business/ct-bright-farms-marianos-0720-biz-20160719-story.html

months, this farmer needs to realize profit margins of roughly 70%, which is significantly higher than most facilities. This means investors need to approach indoor farming as a longer-term investment and indoor farmers must invest in techniques to manage and reduce operating expenses.

3 Technology

The data-driven systems that are moving indoor farming forward.

The future of the industry is data and technology driven. Growing in a climate controlled environment enables growers to realize massive efficiency gains by implementing small changes. As a result indoor growers have large technology budgets and are investing in technologies to improve operations, crop quality, and yield.

A climate control system is one of the most critical pieces of technology for an indoor farm. This system comprises of sensors (typically recording light, temperature, humidity, CO2) and some level of control for HVAC and lighting equipment. Achieving optimal climates within an indoor farm is the most important factor in achieving the increased yield numbers reported by indoor farms. However, the level of sophistication among climate control systems varies significantly.

Selected manufacturers of climate control systems

Of those surveyed, 54% of farms have climate controls systems and 74% of those systems are connected to the internet. There are a handful of leaders

in the climate controls market, including Priva, Argus, Link4, Hortimax, and Hoogendoorn; 45% of respondents have one of these systems. Of respondents, 29% have a custom system, ranging from HVAC systems on timers to proprietary sensor and controls systems developed in partnership with universities.

Maintaining optimal climate control isn't the only priority for indoor farmers. In fact, managing operations more efficiently and lowering cost of production are growers' most pressing goals when it comes to implementing new technology.

Growers are already achieving high yields by using climate control technology and by nature of growing indoors, though they still have a large technology budget for improving yields. On average, growers have an annual budget of $12 per square foot to invest in technology for both increasing plant yields and managing operations more efficiently. Growers have an annual budget of $15 per square foot to invest in technology to improve crop quality.

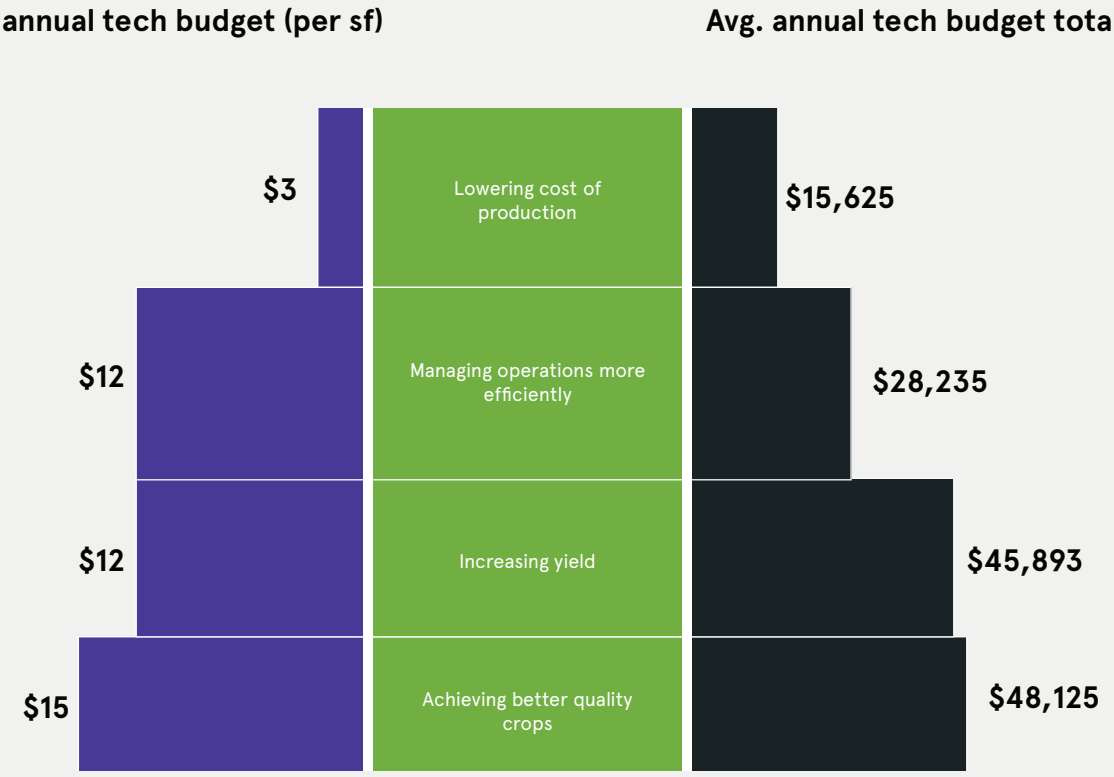
Which technologies are growers investing in?

Topping a list of new technologies of interest to farmers, 39% of growers are interested in purchasing a farm management system in the next year; 28% of growers are interested in purchasing post-harvest automation systems, 28% are interested in purchasing LED lighting, and 27% are interested in purchasing climate control systems. The lowest priority item listed was organic nutrients.[1]

Farm management systems help growers cut down on the time spent collecting and analyzing data as well as the cost of hiring a growing consultant.

1 — Respondents could select more than one option.

Annual technology budgets for production priorities

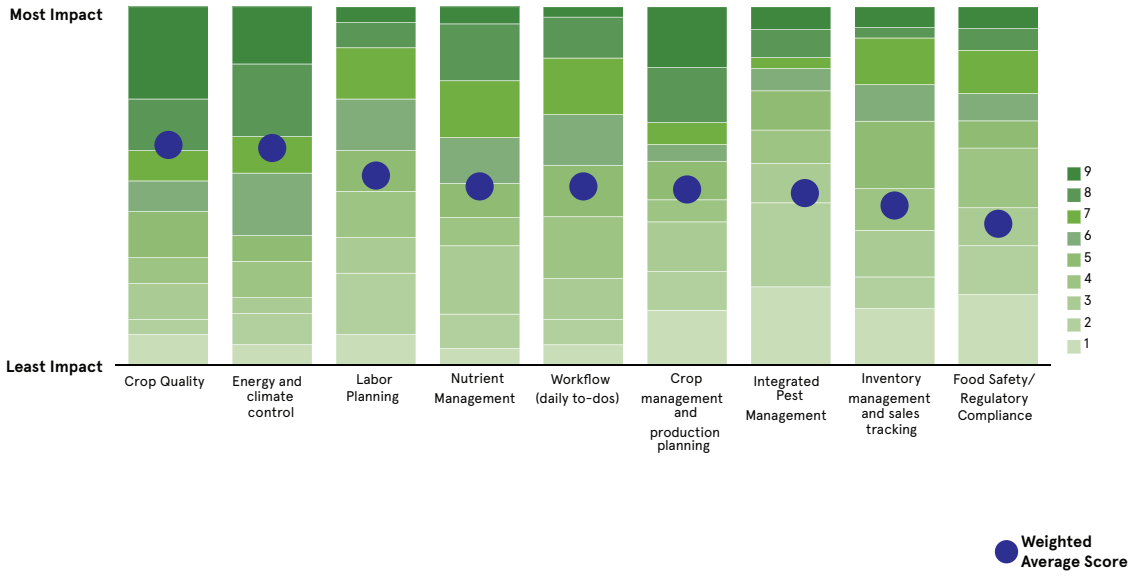


Of the 38% of respondents who reported hiring a growing consultant, about half spend between $5,000 to $20,000 in a given year on such consulting.

With farm management systems, growers have access to data and insights into their operations, and they see the value in such analytics. Of those surveyed, 90% of growers believe they can increase crop yields with data analytics.

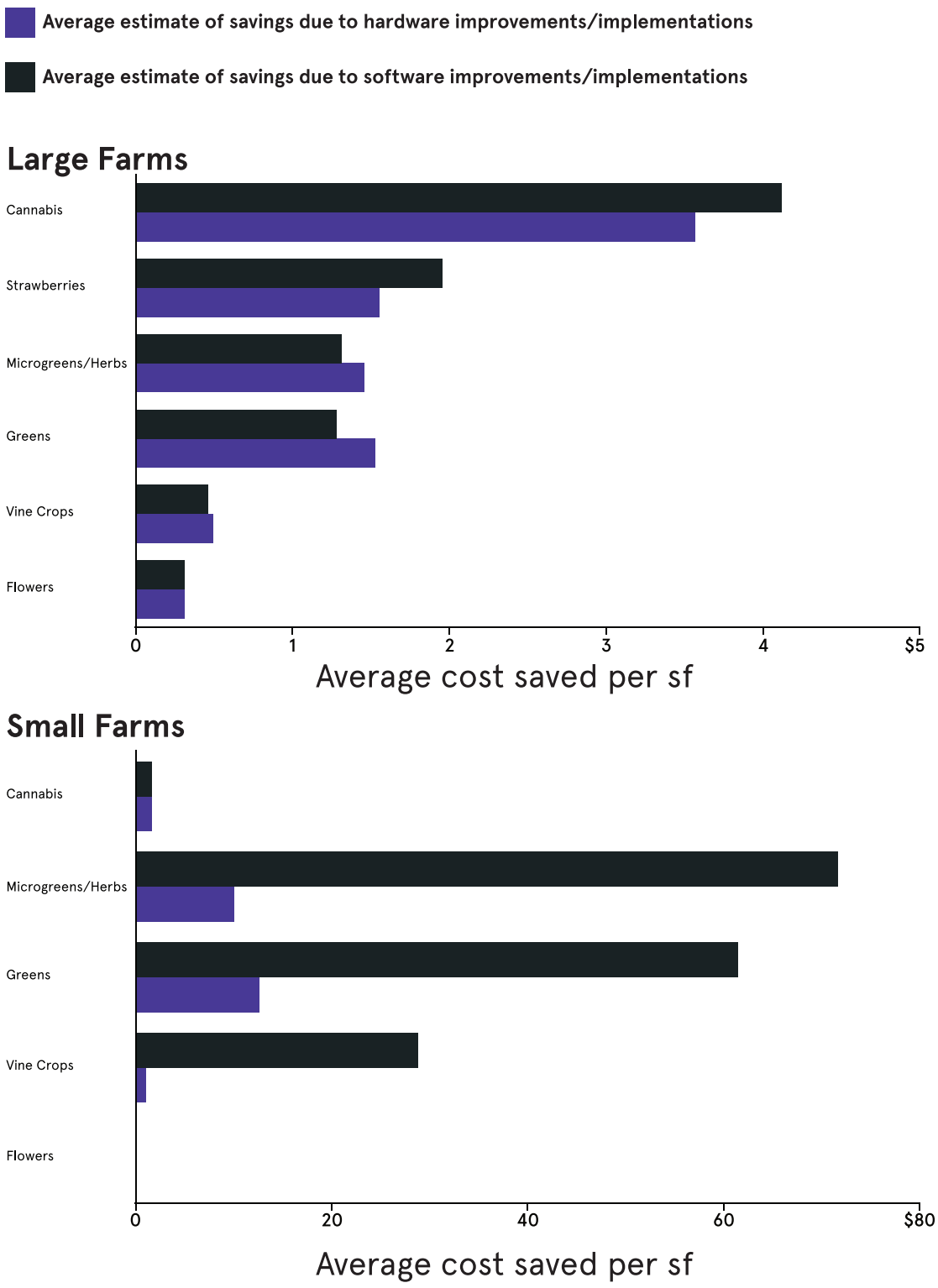
When asked to rank the operational processes on which data would have the largest impact, growers ranked crop quality and energy/climate control first. Impact is defined here as cutting costs and/or increasing yields.

Top ranked processes where data would have the highest impact



Growers recognize the amount they could save with both hardware and software upgrades. Small vertical indoor farms report large savings expectations — on average, microgreen/herb farmers reported possible software savings of $71 per square foot. Larger farms show a range of $0.05 up to $7.00 in savings per square foot with software and hardware improvements. Cannabis growers estimate the largest benefit from technology improvements. As yield efficiency increases, so does the impact of technological improvements.

Annual potential savings due to better technology



4 Market & Future

A look at the benefits from and challenges with rapid market expansion over the next five years.

With the growing global population and increasingly scarce natural resources, indoor farming is on the rise. The flexibility in crop selection encourages the disruption of traditional agriculture markets. Because of the ability to customize the growing environment and ensure stable crop production year round, more farms are exploring expanding operations to include crops not typically grown indoors.

Not only are the markets for indoor food and cannabis rapidly expanding, new markets are are also evolving. Plant-based production of vaccines is garnering increased attention due to the speed and efficiency of growing tobacco plants indoors and at a fraction of the cost of egg-based production. In the United States, the influenza vaccine market is $1.6 billion[1]. By 2054, a third of the global protein market will be comprised of alternative proteins[2]. Indoor insect husbandry is increasing, with farms raising crickets, black soldier flies, and mealworms in controlled environments.

Do you think you will expand your facility and/or add a new facility in the next five years?

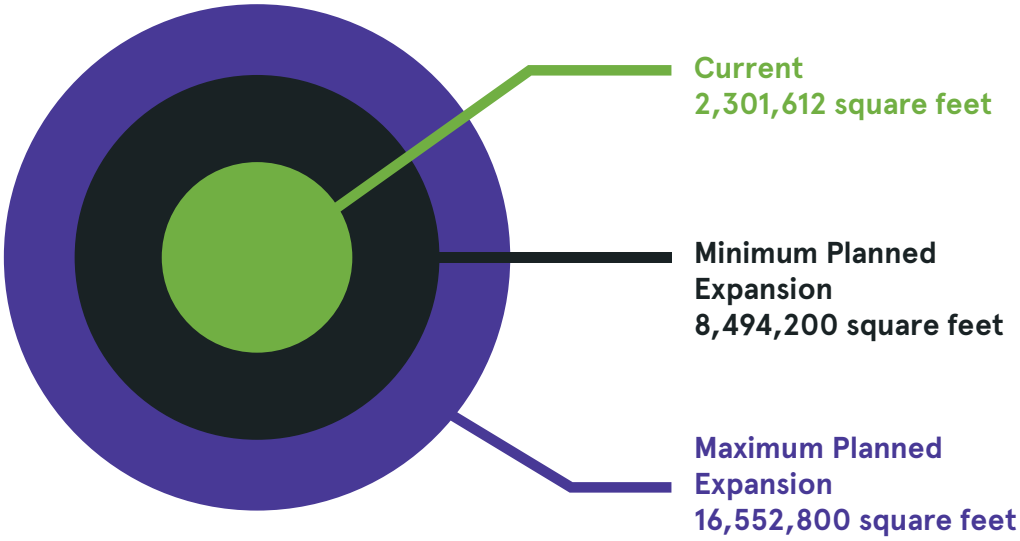
1 — "The $1.6 billion business of flu," CNBC, 2015
2 — "Alternative Proteins to Claim a Third of the Market by 2054," Lux Research, 2015

As more growers move production indoors, current operations expand, and new growers open farms, indoor growing methods are quickly becoming a major tenet of our agricultural economy.

The vast majority of growers, 86% of survey respondents, are planning to expand their facilities in the next five years and they're planning on growing significantly. The minimum planned expansion is 4.7x larger than current farm size.

Small farms have big plans - farms less than 1,500 square feet have a planned minimum expansion of 179x the sum of their current square footage. For large farms, the minimum planned expansion is 2.7x the sum of current square footage.

Market Expansion: the next five years



Approximately 9% of the existing indoor farming market in the United States participated in the survey. Based on current reported revenue and the

expected expansion area, these farms will add to the market between $336 million and $610 million in revenue in the next five years. From all existing indoor farms then, this means a market expansion of between $3.7 billion and $6.8 billion during the same period.

Based on current reported revenue and expected expansion area, reporting cannabis growers will add between $102 million and $153 million in expansion revenue to the market in the next five years.

When asked about the most important factors in driving this growth, increased consumer demand for local food and continued private sector investment topped the list. Growers want to see not only continued interest from investors in the space broadly, but also additional financing options for setting up a farm, which was listed as one of the largest roadblocks for industry growth. The biggest barrier listed was the high cost to operate indoor farms. These challenges present opportunities for entrepreneurs and will require interdisciplinary partnerships.

5 Interviews

In-depth thoughts on the state of indoor farming from survey participants.

Jason Green

CEO & Co-Founder, Edenworks

Edenworks was founded in 2013 with an R&D facility in Brooklyn. In the next six months, the company will open their first commercial production facility.

Jason Green is a bioengineer and the CEO & co-founder of Edenworks. He says that the company's decision to grow with an aquaponics system is based in the complex ecology of soil. Recreating the natural richness of soil with a sterile fertilizer source is a challenge many hydroponic growers think about. Nearly four years ago, Edenworks decided to emphasize microbiota and capitalize on the natural composting and symbiotic relationships in aquaponics to achieve that richness as much as possible.

The horticultural side of their system is a custom vertical farm that grows microgreens and baby greens, marketed as packaged salad. Edenworks has done a ton of experimentation with growing different varietals and will maintain the R&D side of the business moving forward. Fish are grown in separate tanks and are sold to wholesale fish purveyors. The commercial production facility will be 12,000 sf and will produce about 150,000 lb of greens a year and 50,000 lb of fish.

Data permeates all aspects of the Edenworks business. With an analytical team coming from fields like applied mathematics, industrial engineering, and robotics, a quantitative mindset begins in the design phase and continues through production. The company has developed hardware to capture and associate data in real time. Their sensors and enterprise resource management software continuously capture operational data across the facility, from temperature variations to seeding density, and feed that information back into algorithms that inform future design and operational decisions.

Green says one of the challenges in indoor farm operations is efficient labor management. Indoor farms can lose out on the economies of scale that benefit large outdoor operations. The company is building tools to disrupt common labor management practices in order to optimize and gain back those economies of scale. Operations at the facility are viewed as manufacturing processes, and Edenworks has developed algorithms for labor planning in order to schedule activities on the `line' with precision. Green contrasted Edenworks' `process manufacturing approach -- bringing the product to the process' against the `discrete manufacturing' approach that many other indoor farmers use, "bringing the process to the product."

In the coming years, Green is excited to leverage technology and validate the business model and algorithms they've worked so hard to develop. Edenworks has plans to expand beyond their new facility and become a distributed solution to the local issue of fresh, quality food availability in the coming years. They believe that developing hardware and automation is important, but the ability to scale and provide a greater volume of quality food to a wide range of consumers is even more important. Edenworks is interested in organic certification, but not concerned with it, citing consumer survey data supporting preference for local over organic produce. Accordingly, the current focus is increasing the efficiency and availability of locally grown food.

Green says that the current food distribution system wasn't built with freshness as a priority – US consumers aren't eating the highest quality greens possible, because produce can spend a week in transit from production centers in California and Arizona before reaching the grocery store. However, indoor farming changes the freshness game, especially when businesses focus on quality, yield, and cost reduction. This enables products like microgreens to be a part of the larger salad category. Indoor farms have little penetration into packaged salad currently due to the scale disparity between the nascent

indoor farm market and the mature West Coast salad industry, but Green's thesis is that Edenworks and their contemporaries will change that over the next 2-5 years.

The Edenworks team enjoys a meal together once a week! Green: "we can talk about data and process engineering all we want, but if we can't find an hour to enjoy the fruits of our labor together, what's the point?"

Daniel Christensen

Owner, Strata Farms

Strata Farms is a startup farm, working on optimizing plant growth in an urban environment. It is located in Portland Oregon and opened in 2015. Daniel Christensen is a hydraulics civil engineer and grew up on a farm, where he learned that a farmer must be really good at the growing process for the business to survive. His interest in indoor was piqued by the inefficiencies of outdoor farming and the food waste/quality decrease by the time produce is actually in the hands of the customer. Strata is an indoor vertical farm with hardware that Christensen developed himself. At first, the farm grew both microgreens and basil but shifted to 100% microgreens due to demand and better margins. The farm is approximately 420 sf and regular production capacity is 40-50 lb per week but full capacity is 250 lb.

Strata Farms is self-funded by Christensen and is currently breaking even. Lights are the most expensive thing to buy, and labor and distribution are also big expenses for Strata. Christensen is considering adding an Autogrow system for controls or working with an electrical engineering firm that's developing software/hardware controls for the cannabis industry. Christensen believes it is very valuable to examine all the parameters of a growing system on a granular level. He is very interested in tracking data when he has a bigger greenhouse. For now, his process is based on empirical observations, since he has a solid growing process and can focus on tweaking parameters that make a difference in the final product.

Christensen believes that indoor farming is very profitable, but there has to be a market for the products, and success depends on your skill as a grower. He would like to expand his grow area by purchasing a warehouse or greenhouse;

or he'd like to build, distribute, and service indoor vertical systems. He currently has many clients and expansion in the coming five years depends on building a team.

Strata sells direct & wholesale to consumers via two of the biggest farmers markets in the area and a local grocery store. He also sells direct to high end Portland restaurants, and delivers to some campuses and large offices. Distribution is challenging as the farm is currently small and family run, and produce must be delivered to all these locations in a refrigerated van or coolers. Christensen believes that the current food distribution chain doesn't fit very well with the shelf life realities of fresh, locally grown produce. This is one of the issues he sees in the industry: even though you can farm in urban areas, you have the challenge of getting the food that `last mile' to the consumer.

Christensen is excited about the indoor farming industry because it brings different fields like agriculture, tech, and engineering together to disrupt the food system and distribution chain. He believes the industry will continue to grow if farmers maintain the highest quality product possible, and if they are open to collaboration with each other.

Thanos Papanikolaou

Senior Agronomist and CTO/Co-Owner, Phos Gourmet

Phos Gourmet is a well established agricultural operation based in Greece. The farm initiated operation in 1965 and installed their first hydroponic facility in 2000. They grow flowers, ornamentals, olives, fruits, trees, and vines in open field farms, and additionally operate a two hectare hydroponic greenhouse where various vegetables are grown. Thanos Papanikolaou, Senior Agronomist and CTO/Co-Owner of the facility, says that the farm has always been a leader and early adopter in regards to technological progress in close collaboration with the Agricultural University of Athens. The hydroponic farm has implemented various equipment update projects over the years since it was established.

Year round use of the facility and differentiation of products are some of the deciding factors in growing multiple crops. A vast majority of the farm's revenue comes from tomato production. For plum tomatoes, Papanikolaou says that production capacity is 100 tonnes.

Phos Gourmet hydroponic facilities are proud to use an entirely "MADE IN GREECE" custom climate control system. The company has not considered using other systems due to lack of support for those systems in Greece and, most importantly, high prices that are not competitive. Their custom system is continuously developed and updated to keep up with the latest developments in sensor technology. Papanikolaou believes that data can have a big impact on crop quality and integrated monitoring of the crop.

Phos Gourmet is self-funded and has been profitable since the first year of operations. Papanikolaou reports that the biggest expense category by far is

labor. The workforce necessary for optimum production is approximately 20 full time workers per hectare. Each worker has a 47 hour workweek, and the entire workforce is not always needed in various crop stages such as the early vegetative stages.

Labor accounts for almost 45% of the cost of tomato production, and packaging accounts for 23%. Phos Gourmet strives to locate cheaper packaging suppliers and to maintain reasonable labor costs, both of which would significantly reduce costs for the farm. Another industry challenge that Phos Gourmet is concerned with is the increasing cost of seeds and pesticides as well as the concentration of their distribution channels to a limited number of big enterprises. They are concerned with the reduced effectiveness of the pesticides against new pests and diseases.

Papanikolaou says that technological innovation is the aspect of growing that he's most excited about. He has witnessed vast technological progress in the industry and looks forward to the future. He sees the achievement of top quality produce and the ability to continuously monitor crops as the biggest benefits of indoor farming.

Phos Gourmet plans to expand by 1–5 acres in the next five years; the implementation of the expansion plan relies solely on available funding. The biggest driver of the decision to expand is that hydroponic facilities are the most profitable only when you decide to grow extensively. Papanikolaou believes that organic certification will play a significant role in the near future of indoor farming, since people are becoming widely aware of the health benefits that can result from consumption of organic vegetables. He thinks that prices of organic vegetables will be higher than conventionally cultivated ones.

Papanikolaou strongly believes that the indoor farming industry has huge potential in the coming years, and his company plans to contribute to that growth.

Nick Burton

Owner, Paris Victory Gardens

Victory Gardens was opened in 2012. The farm grows a variety of vegetables for salads and includes a high tunnel, greenhouse, a shade growing area, and raised beds.

The farm began with both a hydroponic system and a retail nursery, but they made the decision to close the retail nursery about two years after opening. Burton has figured out a strong business model and expects to be profitable – his profit margins on salad are 50% on average. The farm's largest expenses are air conditioning and lighting. On any given day, 2-3 employees are present to maintain systems, production, and scheduling. Burton saves time by maintaining monthly and weekly labor checklists.

In regards to climate control, Burton says his system is pretty consistent. His team focuses on systems maintenance and anomaly detection - the only time there is a huge flux is if there's an air conditioning unit issue. Water is checked for nutrient spikes twice a week when seeding occurs, but the farm's reservoirs have been very consistent over the last year. Burton's challenge in Texas is keeping everything as cool as possible with a shade cloth and evaporative cooling.

Burton's business model has evolved over the years and is now focused on value-added sales, which has been a success. Now, everything grown on the farm is processed in a commercial kitchen that's also located on the farm. Victory Gardens produces gourmet salads for an office lunch delivery club, and all produce grown is based on what's going into salads during any given week. A major perk of salad creation is originality – the farm is regularly growing approximately 20 different varieties, which keeps things engaging for both

the grower and the customer. Burton says the team spends the most time on binding and fruiting crops like Sun Gold Tomatoes and English Long Cucumbers because they are so versatile in the salad product. Salads also greatly reduce food waste – for instance, you can chop up butterhead lettuce with tip burn and only use the good parts in the product.

A big part of the product Burton sells is convenience. He has three delivery vehicles that leave in the morning to distribute salads to offices where people are members of the lunch club, which has a 90% customer retention rate.

Burton thinks the challenges of indoor farming change as growers become more knowledgeable. When he began Victory Gardens, he would reach out to other growers and organizations for information. Now, he's sharing that knowledge. Over the years, a grower's process is refined. Even though hydroponic growth is not too complicated, a grower may not be getting the most out of their system when it is initially set up. But over time, yields can get bigger each year on the same system if you pay attention to what's working. Burton says he can shop more efficiently at vendors now, saving money and time by forecasting upcoming farm operations and better understanding things like seed volume needs.

On January 23, 2017 Burton will launch a consulting business called `State of the Soil,' a media company for growers that will help them optimize their marketing strategy. Burton believes that the most important part of indoor farming is to identify and qualify your market before you even open your farm. Sales and marketing are completely different. Often, he says, growers view restaurants and Whole Foods as the ultimate goal for their business, but that's not always the best for the local market. It's important to bring tremendous value to customers and Burton has found that convenience is a huge key to actualizing sales.

Victory Farms is excited for the future of the indoor farming industry. They see younger consumers these days with a deeper knowledge of vegetable varieties, who are informed and ready to buy local. Burton also thinks that we're far from peak local food consumption, that value-added sales will continue to increase, and that local indoor farms will become even more linked with the culinary field. Collaboration between farms is also key to the future of the industry.

For more information on State of the Soil, please see http://stateofthesoil.com/

James Brady

Owner, Con10u2farm L3C

James Brady was born and raised on a farm. He is a veteran and his mission now is encouraging veterans to get involved in urban agriculture. In 2012, he trained on hydroponics, vermiculture, and aquaculture at the Archi's Acres in San Diego (VSAT) program and has been producing adaptive growing modules ever since.

Brady runs Con10u2farms, a social enterprise business focused on teaching people to grow food in small spaces. The goal is not to secure 1000 acres in a city, but to quickly grow in small places with no environmental footprint while employing community members. Brady estimates that his systems could create 21 jobs per acre. Partnerships are critical to his business model. Like minded partners, such as hospitals or community organizations, fund the systems. One of his first partners was the Sacramento County Health Department, through which he's placed growing modules in schools. By next summer, Brady expects to be profitable with some of the new partnerships in his pipeline. With that revenue he plans to create a therapeutic environment with living wage jobs for veteran farmers or other marginalized groups, such as ex-convicts or senior citizens.

The growing system is designed to reduce the issues that people encounter in raised beds, which require a lot of maintenance and typically deteriorate over time since they need to be refreshed seasonally. His growing system is designed as a one time installation that requires very little maintenance. At first, worms keep the soil-based system aerated and plants are watered with a recirculating drip system that captures drainage, stores it in a reservoir, and recirculates it.

Recirculated water means the systems use 90% less water than they otherwise would. Brady has also developed an educational add-on option: for the second year of operating the system, a school can decide that they want to convert to a hydroponic system with a floating raft or misting system. During year three, they have the option of adding a fishtank. Sometimes schools also request solar panels, a greenhouse to enclose the module, or a buried 50 gallon drum for rain recirculation — all of which can be easily added, as the system has been designed with these add-ons in mind.

Brady is also partnering with professors at UC Davis to develop a curriculum for an after school program focusing on macrobiology and nutrients. He provides a testing kit with his growing modules so kids can start immediately understanding organic food in small spaces. He plans to include food security in his curriculum to encourages kids to get involved in agriculture at a young age.

A large greenhouse is pretty expensive, but Brady's modules make farming more accessible and avoid the need for city permits. People can find a vacant space and can put in a small system without touching the city's regulations. A grower can be growing food directly after propagation, and harvesting 6-8 weeks after. Hundreds of different varieties of vegetables can be grown in his container farm modules.

The cost of Brady's growing modules is low and very competitive so that schools and people with grant dollars can afford them. Even though so many health issues can be traced to nutrition, and adequate nutrition is an issue with a large pool of grant money, lack of community participation and outreach means that local communities often don't receive that grant money. According to Brady, other roadblocks for container farm products include maintenance of crop quality and lack of existing technology.

Brady has a testing lab at his farm, where he experiments and collects data. For example, his growing modules focus on water usage; at the lab they experiment with how long it takes to drain water out of the grow beds. With his knowledge about vermiculture, Brady has developed additional profitable products on his worm farm: all-natural worm compost and worm tonic (a concentrated fertilizer), which he plans to sell on the farm's website to consumers anywhere. He would also like to eventually be able to ship his system to anyone that orders it in the format of a kit with instructions. Shipping the system would be a challenge, but it's a goal.

Brady believes the future is fantastic for urban agriculture and indoor farming. Urban agriculture can help reduce extensive carbon footprints and uses vacant spaces that have been otherwise abandoned. Many cities are adopting urban agriculture ordinances, starting up a whole new local economy. As his business scales to larger facilities, Brady plans to make deliveries via electric vehicles. He values the use of recyclable organic waste to grow food, and even thinks that growing indoors could be a way to capture carbon credits. Indoor farming can expand way beyond traditional methods to grow in small spaces, shipping containers, or even long bed trucks. Urban agriculture is coming into its own, and we haven't even scratched the surface of its potential.

Rich Andrews

Owner, Nuetech

Rich Andrews is an owner at Nuetech, a manufacturer of LED grow lights. The company was originally involved in the engineering of computer and cell phone lighting. They used their familiarity with LED technology and brightness optimization to begin developing LED lighting systems for indoor farming. Over the last few years, the company has been in an R&D phase, and they are now rolling out products and consulting with prospective clients. Nuetech's mission is to develop the leanest operational lighting possible: the lowest wattage lights that enable the max possible yield for clients.

Nuetech continues to refine their lighting product with feedback from experienced growers. It's hard for growers to gather information on lighting systems online, so Andrews believes that the best way to showcase the product is by inviting people to come taste and experience the plants grown with Nuetech LEDs. It's also important to communicate the potential return on investment from lighting upgrades, which varies by state and city, in order to refute misconceptions about LEDs being super expensive.

The company has done plant growth testing side by side with LED lights from other prominent manufacturers - Nuetech lights perform consistently and just as well. In comparison to T5 lights, they've proven more rapid root growth. They've helped farmers solve growth issues via lighting tweaks, such as red lettuce that's not expressing red pigmentation.

Nuetech has a few different target markets. Currently, they are focused on testing their product in vertical farms. They also plan to support greenhouse growers who supplement ambient light with LEDs, and the lighting-intensive

cannabis industry. In the coming years, R&D will include a focus on seeds, developing seeds that are optimized to grow under LED lighting.

Andrews is excited about the industry because of the accessibility and health benefits that indoor farms can provide. He believes that locally sourced food makes financial sense, is an educational opportunity for the community, and that food grown indoors has a great taste that will get consumers excited about healthier foods. Having spent time with clients that are using Nuetech LED lights, he feels that the industry is gaining visibility and that people want to learn more when they hear that their produce is coming from a local indoor farm. He also thinks that anyone can start an indoor farm — even with a few LED lights in a closet! — and that growing plants is rewarding. People feel accomplished when they plant a seed and create a product.

Andrews thinks that basil and cannabis are the most profitable crops to grow indoors, and that selling direct to restaurants is a great way to profit. Indoor farming is a great way to be sustainable, using less water, and with LEDs less power as well. Some challenges in the industry include zoning regulations and the current rulings on hydroponics and organic certification. According to Andrews, a user friendly farm management application would be incredibly useful. He mentioned that many farms are family operated and cross generational: kids on the farm are particularly into technology. The most useful functionality, in his opinion, would be anomaly detection and alerts when temperature exceeds a threshold or a water line breaks.

Andrews also believes that it's important for large greenhouses to perform well and set a strong example for the rest of the industry, showing that indoor farming is a sustainable business model that's worth investing in.

Jessica Vaughan

Hydroponic Grower, Jacobs Farm Del Cabo, Inc.

Founded in 1980 as a small organic family farm, Jacobs Farm Del Cabo, Inc remains committed to benefiting people and the environment for generations to come.

Jacobs Farm Del Cabo, Inc is a wholesale commercial farm that has ten ranches in the central California coast, three of which are greenhouses. The farm focuses on culinary herbs but also grows a variety of vegetables and fruits. Organic practices are a central tenet of the Jacobs Farm Del Cabo, Inc business, and all crops and ranches are certified organic, including hydroponics.

Jessica Vaughan is a hydroponic grower at one of these greenhouses, which covers about 10 acres. She maintains a regular crop of organic hydroponic basil while doing seed research for the company. Vaughan was in the tech industry and returned to school to focus on plant science about four years ago. She became very interested in organic growing practices and controlled environment agriculture due to the precision and efficiency involved. Now, her specific focus is organic hydroponic systems.

Vaughan says that the farm is always working on new product development, which is most exciting for her. Her work involves updating and improving production models for various products so that they can be grown with less disease and better yield. The farm's Mexico operations are also developing new tomato and pepper varieties with a focus on flavor improvement.

The farm has been around for 37 years and is focused on optimizing and upgrading the spaces they already own. The greenhouse where Vaughan works has been around for decades and was originally designed to grow cut flowers, so there are still plenty of upgrades on the horizon in order to fully optimize for vegetable production. According to Vaughan, this is the case with many greenhouse structures in the area that were originally designed for cut flowers. Just as consumer demand shifted outdoors from apples to berries, indoors it has shifted from cut flowers to vegetables and herbs, and may shift again to cannabis in the years to come.

Vaughan's facility has a climate control system, but she utilizes her own methods for collecting data and she pays close attention to fluctuations in metrics. She's seen various technologies emerge in the agriculture space, but still notices a discrepancy between farmers and the companies developing that technology. She's still looking for tech that effectively bridges the divide between those groups via great design, modern technology and the internet, and deep roots in practical application.

As someone who works on a farm that's been established for many years, Vaughan thinks that older farms are open minded to new technology. However, it's crucial to set clear expectations from the start, provide adequate follow-up, and detail the true usability of any information derived from new tech. Established farms want to know that the specific information they'll be getting from a product, whether hardware (LED lights) or software, links to practical application and works with existing systems.

Managing labor and workflow is a challenge for many farms, and farms in the central coast face an additional labor related challenge. The berry industry has become very profitable in the last few years with an uptick in demand, and seasonal workers gravitate towards berry farms for the higher wages

they offer. Jacobs Farm Del Cabo, Inc only employs year round crews, but the labor force still tends to shift seasonally because of berry farms. The farm can provide things like benefits to employees because of its year round employment model.

Reducing energy consumption is a big focus for the farm, and they've done energy audits with PG&E to identify focus areas for energy efficiency improvements. Land cost in the central coast is extremely expensive, so it is also important to increase yield per square foot and to reduce waste.

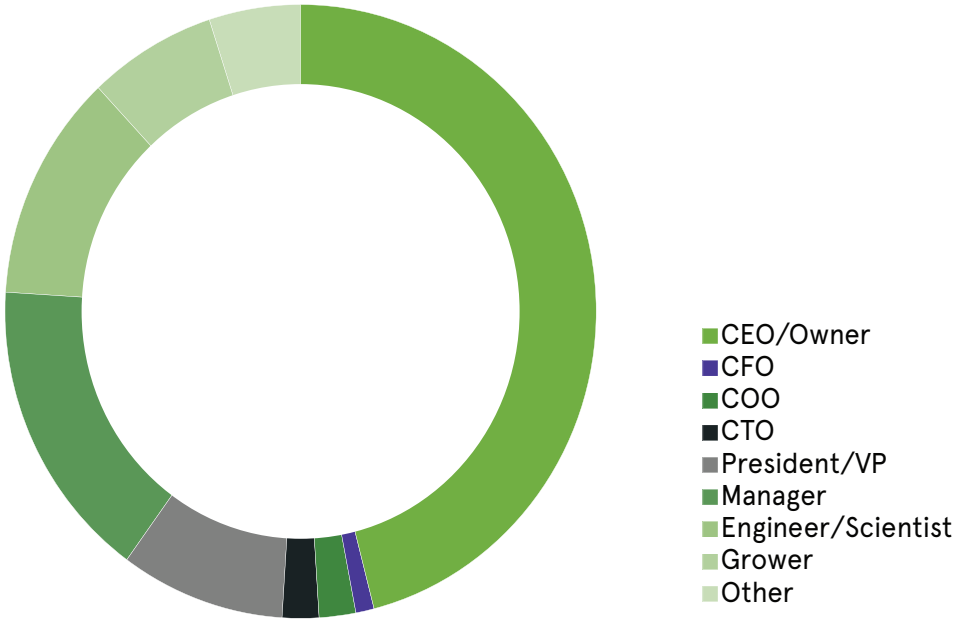
Vaughan believes that the pending ruling on USDA organic certification for hydroponics will dictate the future of the hydroponic agriculture industry. There is a large amount of growth occurring in the world of hydroponic farming. Without the possibility of organic certification, Vaughan thinks that hydroponic farmers may lose the motivation to continue that pace of growth. Organic farming allows growers to push boundaries and be innovative in farming practices, so limiting organic certification to traditional in-ground production techniques means interesting new methodologies and highly efficient techniques could be lost and the clock would be set back on progress that's already been made.

Jacobs Farm Del Cabo, Inc is also working to make organic growing practices viable and feasible for regions outside of the US, such as Mexico and Tanzania.

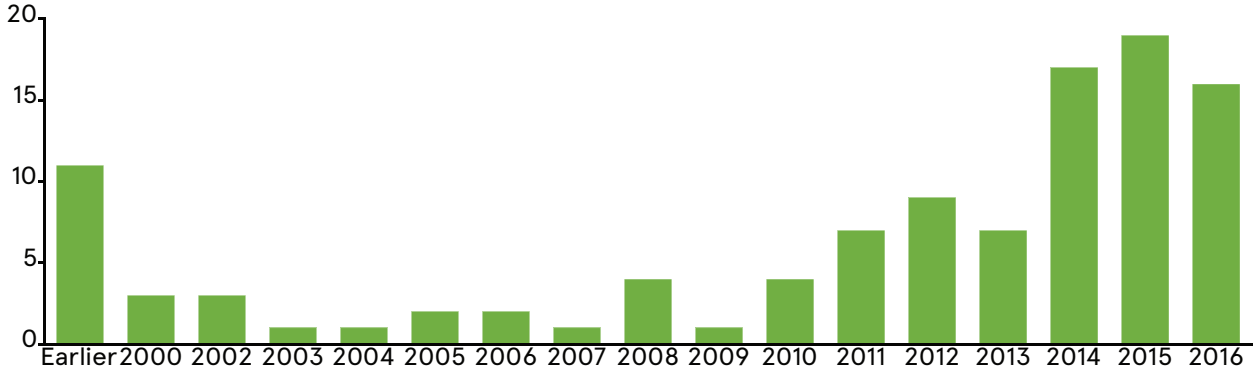
6 Appendix

Additional survey insights.

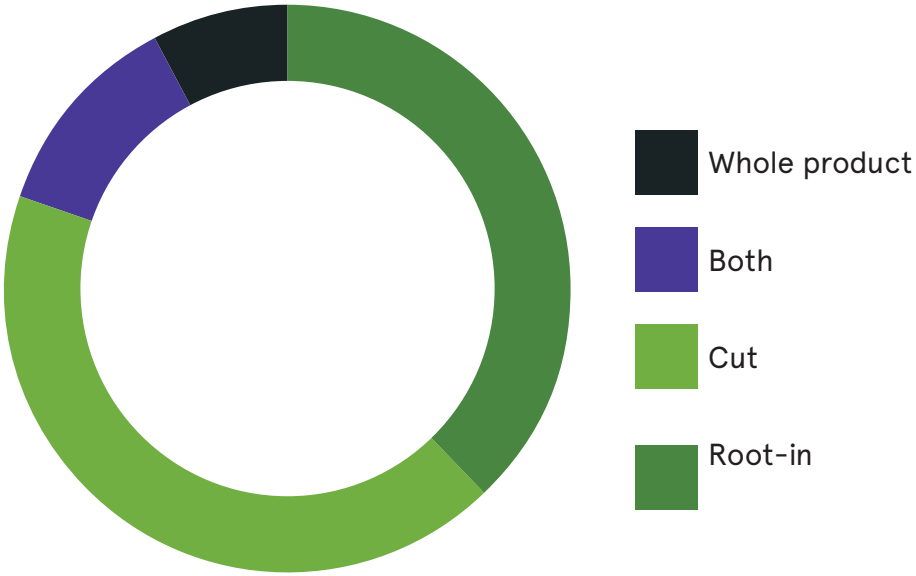
Titles of survey respondents



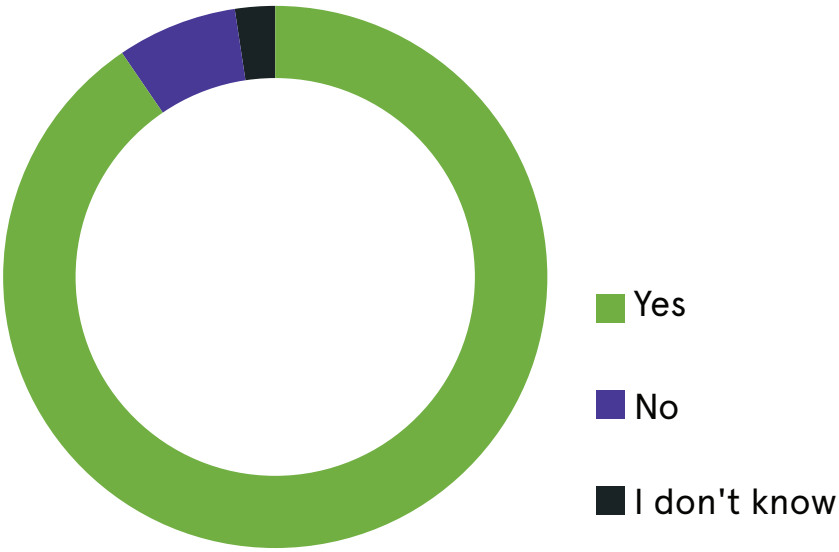
Timeline of farm openings



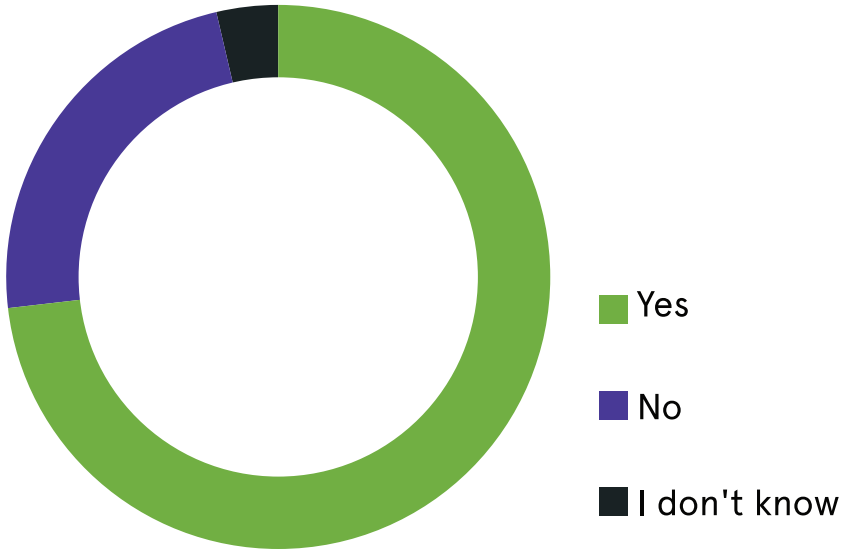
Breakdown of respondents who sell root-in, cut, or whole crops



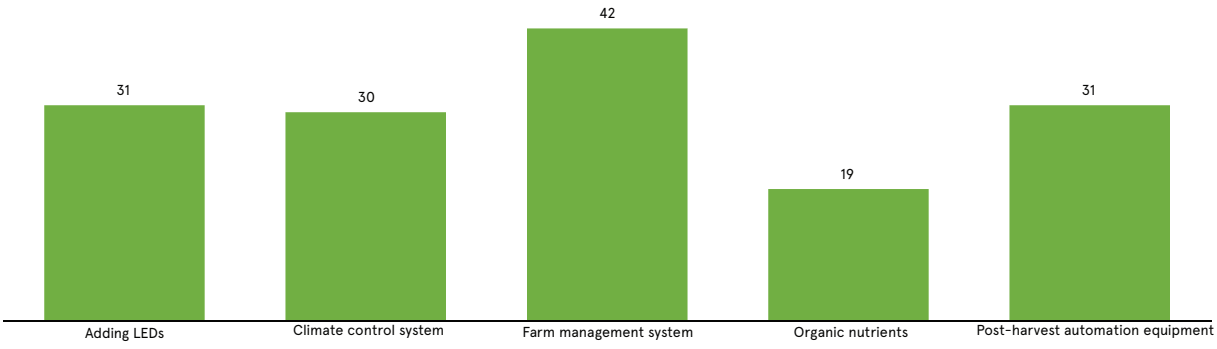
Percentage of farms with internet access



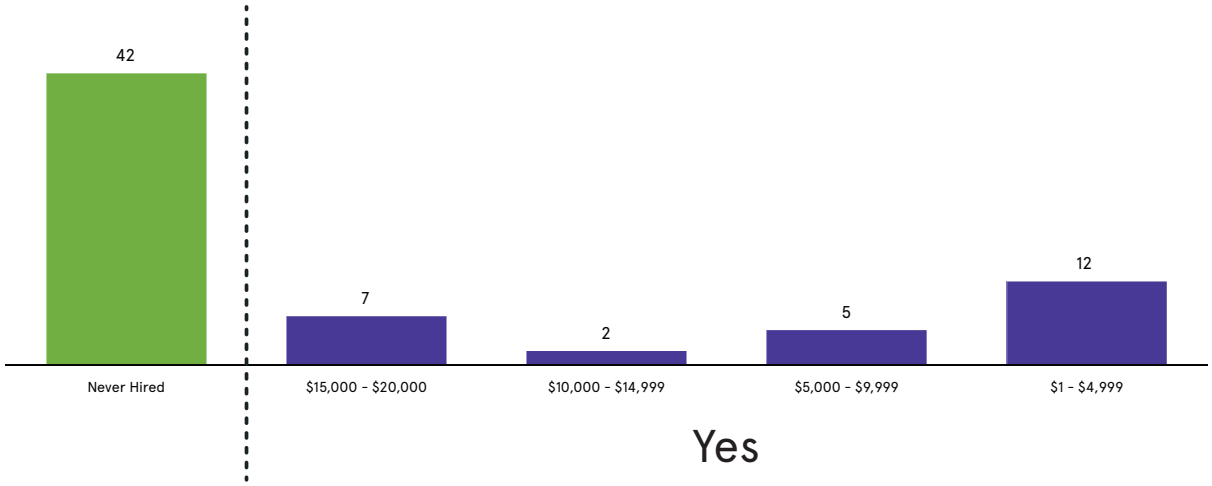
Percentage of farms with climate control systems



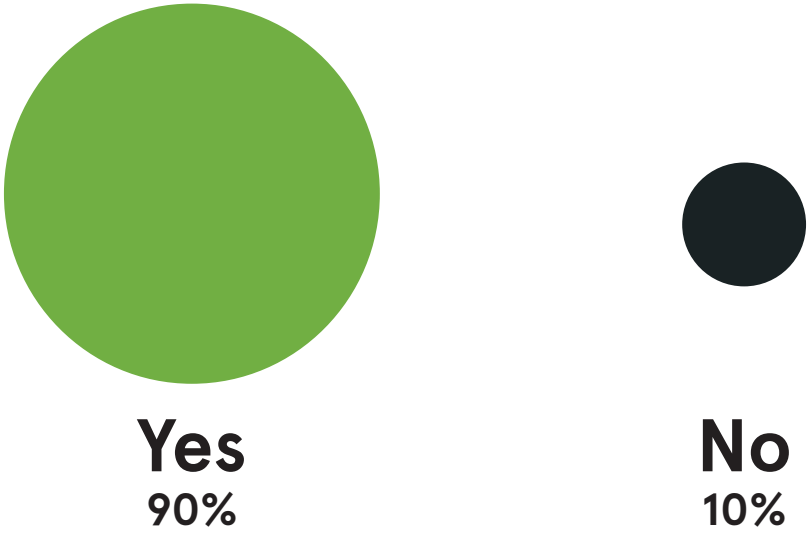
Technology and farm improvements intended to be implemented in the next year



Percentage of farmers who hired a growing consultant and annual cost

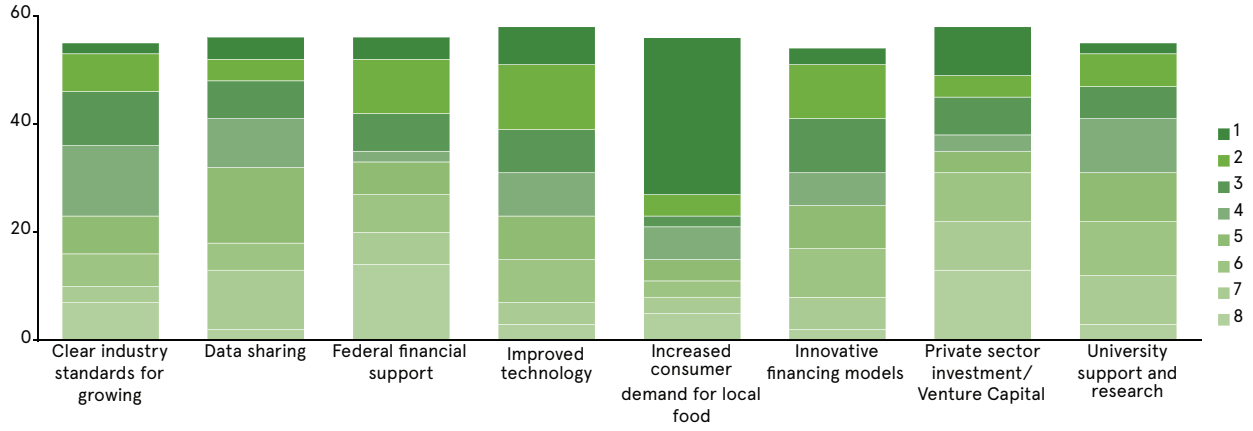


Percentage of farmers who believe they can increase crop yields with data analytics



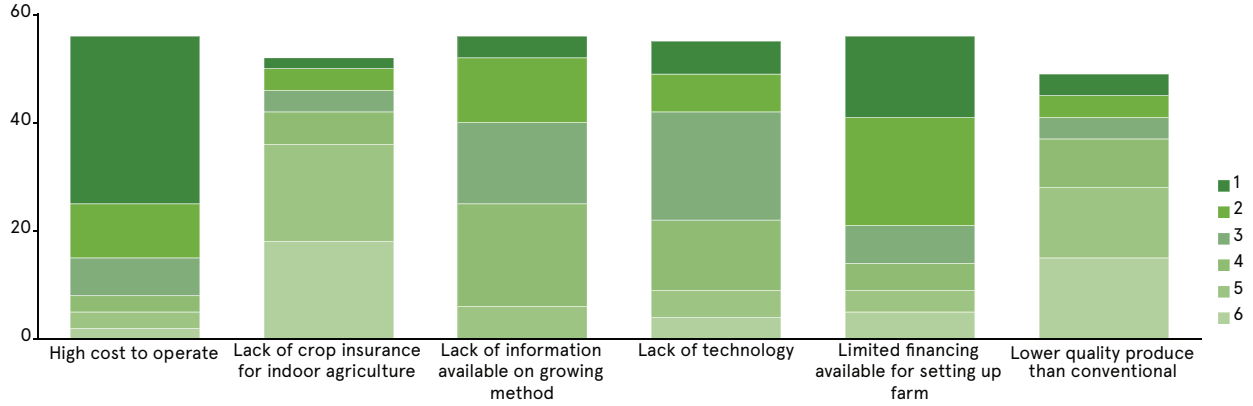
Top ranked driving factors for industry growth

Ranked 1 (most) - 8 (least)

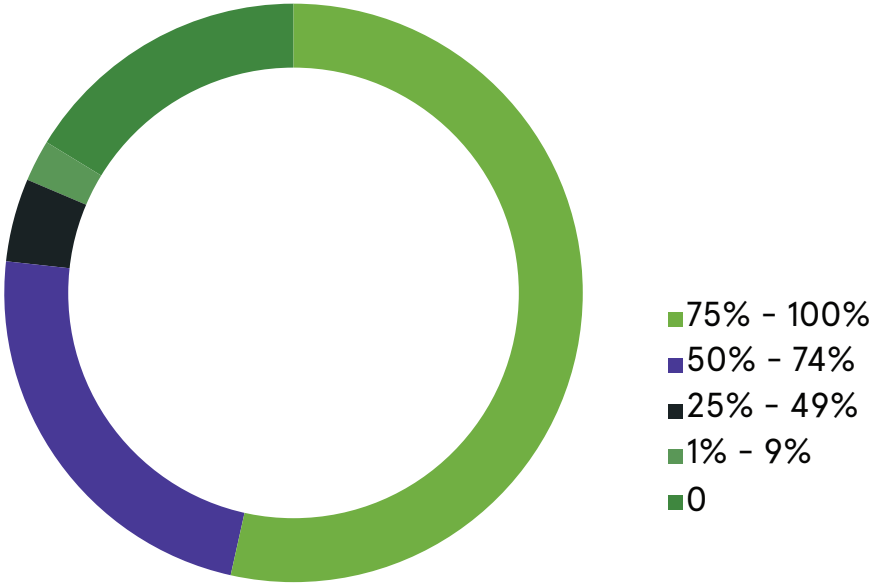


Top ranked roadblocks for industry growth

Ranked 1 (most) - 6 (least)



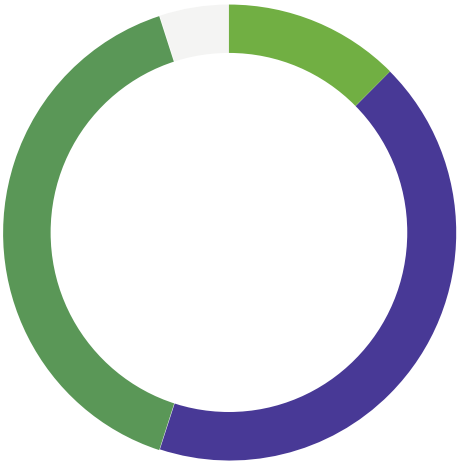
Percentage of repeat orders for individual farm sales

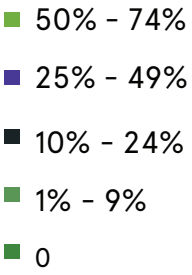


Percentage of total costs resulting from:

Processing/Packing

Marketing/Distribution





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