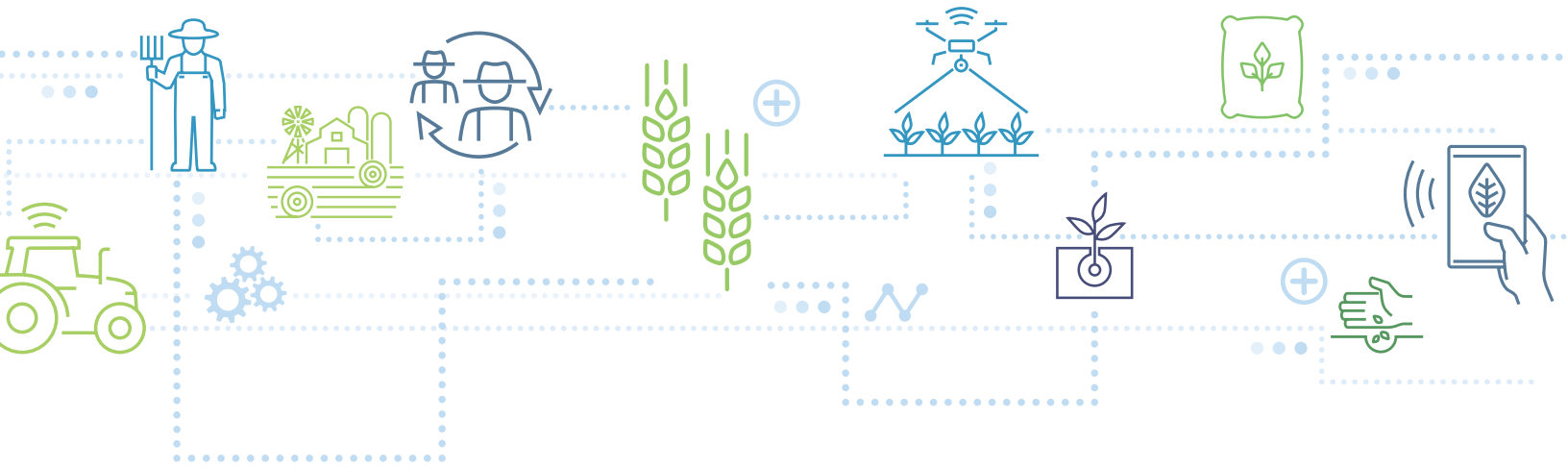
software.org
BSA Foundation

Every Sector Is a Software Sector: **Agriculture**

Agricultural Opportunity Is Growing With Software

May 2019

www.software.org



Agricultural opportunity today is rooted in software. Software innovations have quickly become essential tools for the day-to-day operations of the agricultural sector — improving the way everything from farms to tractors are run. Farmers have rapidly adopted breakthrough software advances that are enabling them to solve problems in ways previously unimaginable, thereby maximizing agricultural opportunity.

With enormous potential at hand, we are just at the beginning of what digitalization, data, and software innovation can deliver. Software developers are forging ahead with tremendous improvements in the way farmers grow, feed, harvest, and distribute food — boosting yields and cutting costs. Thanks to new advancements, software is now harvesting data from seeds, satellites, and sensors to help farmers make better decisions about what to grow, how to grow it, and when to grow it. It enables them to fine tune their operations with digital precision for maximum results. By being more precise, they can reduce the amount of fuel, water, and fertilizer they use; make better decisions about exactly when to harvest for maximal yield; and track food freshness from their farm to your fork. The effects are profound: when widely deployed, precision farming technologies can increase global crop yields as much as 67 percent and cut food prices in half.[1]

Software is delivering critical intelligence to enable farmers to do more with less:

- Soil sensors planted throughout a farm constantly feed data to cloud-based systems that track the soil's moisture, nutrients, and needs.
- Self-driving tractors and autonomous machines are becoming increasingly common — planting seeds with digital precision, killing weeds with a zap, and reducing overspray by delivering fertilizer precisely where it's needed.
- Data from satellites whizzing across the sky is combined with data from sensors in the ground and hyper-local artificial intelligence (AI)-based weather models to predict a plant's water needs — creating a customized irrigation plan that can go to automatic watering systems that deliver the right drops for each crop.

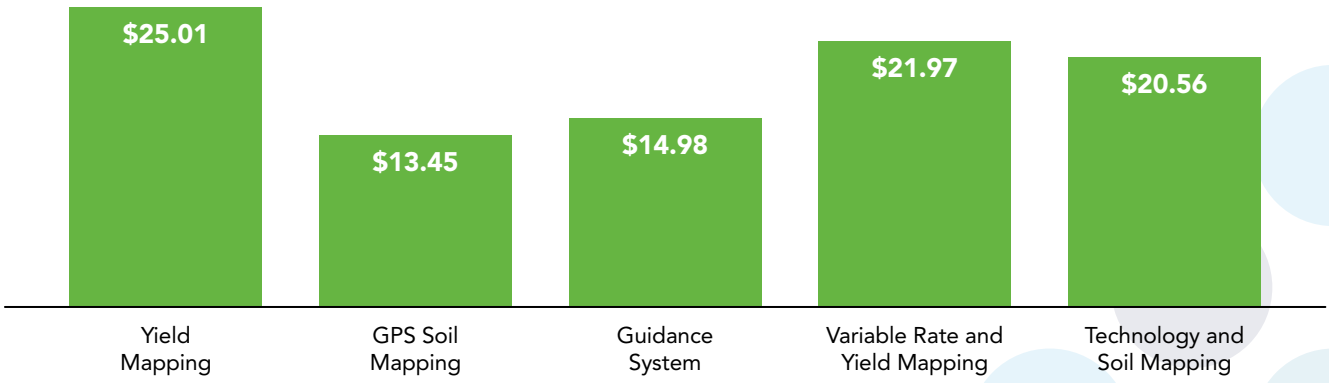
- Drones are taking opportunity to new heights as they buzz overhead with multi-spectral cameras to spot fungi earlier and in ways beyond what a human eye can see — avoiding costly disease outbreaks.
- Fences are being replaced with GPS, as connected livestock collars tell ranchers which animals may have wandered off, may be ready to breed, are potentially getting sick, or need special attention.
- To maximize yields, cloud servers check the weather, market prices, and growing conditions to tell farmers the precise moment to harvest to maximize results.

Software not only pulls all this data together, it puts the information at the farmer's fingertips — giving them more control over their livestock's and crop's progress from any device, anytime, anywhere with broadband. It enables almost everything to be done with greater efficiency, precision, and effect. Software is able to manage the vital supply chain process of getting fresh food distributed, processed, and delivered to your table in a safe and traceable manner — to reduce spoilage, ensure food safety, and cut food waste.

Software innovation has now reached a point where it provides the ability to solve some of the agricultural sector's greatest challenges. Software is helping farmers and ranchers tackle major challenges like producing more food to feed the world's next billion people, making foods that are more nutritious, ensuring crops can be more resistant to drought and diseases, and ensuring robust food safety all the way to your table. These innovations are helping the agricultural community be better stewards of the earth with technologies that can improve sustainability, reduce the use of harmful chemicals, cut greenhouse gas emissions while still boosting yields, and ultimately put more money in farmers' pockets. For example, when software-enabled precision technologies are widely deployed, experts predict they can cut water use by up to 30 percent,[2] reduce herbicide use by 99.99 percent,[3] reduce fuel use by 10 percent, boost crop yields by 70 percent, and cut food prices in half.[4]

Software is helping farmers harvest economic savings. These precision technologies don't just boost yields, they boost the bottom line, too. For example, according to the United States Department of Agriculture (USDA), a typical small family-owned corn farm in Ohio that implements precision farming technologies can save about $2,000 per seasonal corn crop.[5] Large farms can save nearly $40,000 per year with a return on investment of less than two years. More specifically, farms that deploy yield mapping can save $25 per acre, GPS soil mapping $13 per acre, software guidance systems $15 per acre, and software controlled variable rate application technology $22 per acre. Add it all up: software delivers big savings.

Savings Are Sprouting up Everywhere
Average cost savings by adopting software-enabled technologies
($ per acre saved)



Source: USDA Economic Research Service

Recovering Precision Farming Technology Investments

Farm Size	Annual Savings	Years for Return on Investment
Small (800 acres)	$11,000	6+
Average (1,600 acres)	$26,000	2+
Large (2,400 acres)	$39,000	~2

Source: National Geographic, *Farming: There's an App for That*

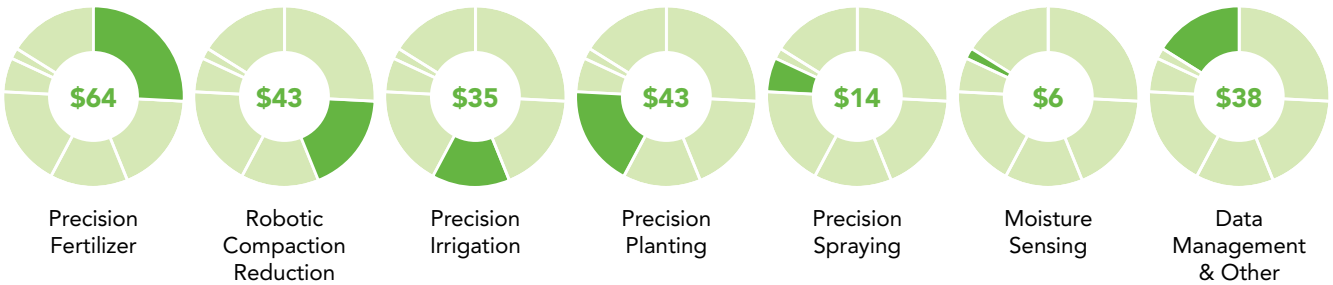
Software doesn't just help grow more crops more cost effectively, it can help grow rural economies, too. As farmers expand what technology enables them to do, technology expands what rural economies can achieve. Technology innovation is a proven engine for rural economic growth. For example, from 2007 to 2016 in Iowa alone, tech and tech-related jobs grew by 83 percent, accounting for almost one quarter of private-sector nonfarm job growth.[6] Already, the top 12 agricultural producing states, representing more than half of all US farm income, employ more than 1.3 million people in software-related jobs.[7] By 2026, these top 12 agricultural producing states are poised to create almost 200,000 new software-related jobs — jobs that often pay more than twice other private sector jobs, in many cases with annual salaries of more than $100,000.[8] And as broadband extends further and faster into rural communities, internet access won't just expand the types of precision technologies farmers can deploy; high-speed internet will expand rural economic diversity and access to the jobs and industries of the future.

But farmers must overcome key barriers to take full advantage of software-enabled progress. Although precision agriculture use is growing rapidly, in 2015 precision agriculture technology was used on less than 20 percent of all farmed land.[9] Too often, farmers may not be able to take full advantage of these software-enabled opportunities because 29 percent of US farms have no access to the internet.[10] Likewise while 200,000 new software jobs are projected to be created in the top 12 farm states alone, there are too few people with the skills needed to take these jobs, leaving many opportunities unfulfilled. Big gains can be made as these barriers are overcome and as more farmers begin taking advantage of software-driven technologies.

The opportunity is so big, studies estimate the addressable size of the precision agriculture market will grow into a $240 billion economic opportunity by 2050.[11] But these opportunities can only be achieved with pragmatic policies that remove precision agriculture barriers by closing the rural broadband gap, overcoming the rural skills gap, and nurturing the growing software innovation ecosystem with pragmatic policies that help it grow and thrive.

$240 Billion Digital Agriculture Opportunity

Billions of dollars addressable market by technology



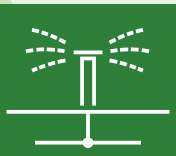
Source: Goldman Sachs Global Investment Research

Software Helps Solve Agriculture's Most Intractable Challenges

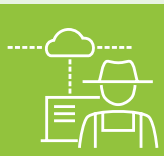
Feeding future generations by boosting yields and cutting costs. By 2050, to meet population growth, we need to produce 70 percent more food than we do today.[12] To help meet this challenge, software-enabled precision technologies can help boost global crop yields as much as 67 percent.[13]

Reducing greenhouse gasses by tackling the largest contributor. Food production is responsible for the largest share of CO^2 emission in the world. Livestock in particular is responsible for nearly half of all greenhouse gas emissions — three times that of all transportation combined.[14] Connected sensors are helping farmers identify ways to cut livestock emissions by monitoring feeding and digestion to optimize their diet in ways that reduce emissions.

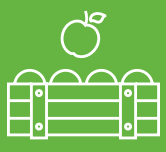
Reducing environmental impact by applying chemicals more accurately. Chemical runoff from over-application of chemicals can affect rivers, streams, and ocean life.[15] Using software-enabled computer vision and micro-dosing technology to deliver the precise doses to meet actual plant needs, herbicide use can be cut by 99.99 percent.[16]



Overcoming a growing clean water crisis by cutting water use. Agriculture uses 70 percent of global fresh water supplies[17] at a time when roughly two-thirds of the world's population live with severe water shortages.[18] Using software-enabled moisture sensors, better weather predictions, and smart irrigation technologies can reduce water consumption by 20 to 30 percent.[19]



Reducing food waste and improving security through better management. Up to 40 percent of food is wasted in the United States, costing approximately $165 billion each year — 50 percent happens during distribution. Sophisticated software is helping manage food distribution more efficiently, improving traceability, and cutting the cost of resolving a food recall in half.[20]



Increasing access to healthier diets with more nutritious foods. Unhealthy diets contribute to 678,000 deaths each year in the United States — including from obesity-related diseases like heart disease and diabetes.[21] Globally, 1.7 million (2.8 percent) of deaths are attributable to low fruit and vegetable consumption.[22] Software is helping scientists develop new plant breeds that grow more delicious and nutritious foods, while also helping get them to the markets that need them most.

Reducing weather-related crop damage with AI-powered hyper-local predictions. Although 90 percent of crop losses are due to weather,[23] crop damage can be reduced by 25 percent using predictive weather modeling and precision agriculture techniques.[24]

Making Smarter Decisions to Feed Future Generations

By the middle of the century the global population is expected to reach 10 billion, requiring the world's farmers to produce significantly more food with about the same amount of land. To meet the needs of future generations, farmers are turning to technology to produce more food with fewer resources.

They are combining soil sensors, imagery from satellites and drones, GPS guided computer-controlled farm equipment, and cloud-based analytics to customize the care that plants receive. For example, a camera equipped precision-guided farm vehicle might use infrared analysis and computer vision technology to assess individual plant health — like leaf shape, stem size, and soil moisture content — to target sprayers and spreaders with the specific resources for healthier plants.

Farmers also want insights into whether a certain seed performs better than others, why a part of the field ended up yielding less, or the exact right time for harvesting to maximize yield. Farmers, for example, can estimate yield improvement by 10 to 15 percent if they are able to find a data management software system that optimizes where to plant "aggressive" vs. "defensive" hybrids.[25]

- **Connecting precision opportunities together.** At the Dancing Crow Farm in Carnation, Washington, they use algorithms to deliver water, fertilizer, and pesticides only to the crops that actually need them. The farm combined Microsoft's cloud-based machine learning algorithms, low-cost sensors, and aerial drones to improve agricultural yield, lower overall costs, and reduce the environmental impact of agricultural production.[26] The drone, for example, uses software to make it easy for a farmer to survey the field using 25 percent less time.[27] One of the keys to this progress is the internet connectivity enabled by using an unoccupied slice of spectrum called "TV White Spaces," which enable sensors to be seamlessly connected and integrated with AI systems in the cloud.
- **Helping farmers focus on success.** Often today, farmers need to consolidate information from multiple inputs to give them a more complete picture of the farm's operations. Trimble's agriculture software, for example, brings together data from different farm equipment manufacturers so farmers can sort through data from different systems for a real-time overview of operations from any location. The systems help farmers focus on success by creating estimates of the cost-per-acre for better decisions throughout the growing season.

> To meet the needs of future generations, farmers are turning to technology to produce more food with fewer resources.

Growing More Crops Per Drop

Agriculture consumes more than 70 percent of the world's fresh water supplies.[28] And an estimated 60 percent of that water is wasted due to overwatering, runoff, contamination, and other issues.[29] To improve efficiency, software advancements like better weather analytics, new satellite imagery, and smarter soil sensors are being combined to help farmers get to the root of their water problems. These technologies are helping farmers grow more crops per drop by reducing water consumption by 20 to 30 percent.[30]

Software is helping farmers use water more efficiently:

- **Putting precision into irrigation.** Farmers are turning to Trimble's Irrigate-IQ water management solution to enable GPS-guided irrigation systems that precisely control every nozzle for highly targeted water application.[31] When implemented, they can reduce water consumption by 30 percent.[32]

- **Using sensor data to precisely deliver the right amount of water.** In California, a state continuously hit by drought, agriculture consumes about 80 percent of the state's water. California's thirstiest crops are almonds. Growing a single almond consumes around a gallon of water.[33] But now, by connecting wireless sensors across a farm, data can be collected, crunched in the cloud, and used to control an irrigation system that drips in water at just the right amount — using 20 percent less water than traditional irrigation techniques.[34]

- **Saving an aquifer by using water with digital precision.** In Kansas, the aquifer is dropping by as much as two feet per year in some counties.[35] Studies suggest that if existing trends continue, 70 percent of their water will be depleted by 2060. As a result, the Kansas Water Office partnered with forward-thinking farmers who are taking advantage of new technologies to identify ways to more efficiently use scarce water resources. T&O Farms combined soil sensors, precision weather predictions, and a drip irrigation system to cuts its water use by 33 percent without sacrificing yield. Across the whole season, the savings translated into about three inches of water saved for the entire crop — water savings that can be readily replicated throughout Kansas.

- **Delivering water just to the vine, to improve the quality of California's wine.** California is also home to a $35 billion wine industry, which is rooted in its ability to consistently produce quality grapes. To maximize the quality of its grapes, E. & J. Gallo Winery turned to IBM's Watson to develop an intelligent irrigation system that uses weather reports and remote sensor data to deliver precise amounts of water to each vine to increase the quality of its grapes. Because of this tailored watering, the winery reduced its water use by 25 percent, while also improving the quality of its wine.[36]

- **Improving the quality and quantity of crops in the developing world.** These technologies can be especially powerful when used abroad. For example, the millions of small-scale farmers in Kenya traditionally don't irrigate for their crops. IBM has stepped up to help Kenyan farmers optimize crop growth and improve food security by managing their water more effectively using Internet of Things (IoT) technologies. The IBM project EZ Farm uses sensors to help farmers understand how much water is in the soil and measure the amount of water in local water tanks. This data is then combined with weather data to plan irrigation times to optimize crop growth, extend the crop cycle, and improve the quality and quantity of crops.[37]

Fighting Pests and Protecting Crops While Reducing Harmful Chemical Use

Each year, as much as 40 percent of the world's potential harvests are lost to damaging insects, weeds, and plant diseases.[38] At the same time, chemical runoff from the overapplication of pesticides, herbicides, and fertilizers can affect the health of our oceans, rivers, and streams.[39] In fact, farmers who don't yet use precision fertilizer technology are estimated to be overfertilizing 40 percent of their fields, and still seeing yield loss on 10 percent of their fields.[40] That's in part because an estimated 95 percent of chemicals sprayed miss their intended target, wasting the expensive agricultural chemicals and raising the toxicity risk for both people and wildlife.[41] To solve the problem, farmers are turning to software-enabled precision technologies to reduce waste by delivering just the right amount of chemical precisely where it's needed.

- **Applying fertilizer in calibrated doses.** Software-enabled technologies now help apply fertilizers in more calibrated doses to meet specific soil and plant nutrient needs, dramatically cutting fertilizer and other chemical use. For example, Trimble's Field-IQ software is a fertilization control system that helps control variable rate sprayers aimed at precisely managing a grower's inputs. Using an integrated system of hardware (precision nozzles, boom adjusters, and spinner speed controls) and its innovative software, the system provides a more accurate seeding and fertilization system to the grower.[42]

- **Using soil sensors to improve nutrient uptake.** Software is also helping improve crop health by optimizing soil pH levels, which is essential for nutrient uptake that can reduce the amount of fertilizer needed and directly impact yields. The growers at Costa Farms in Florida partnered with Microsoft to create a better way to measure and regulate pH throughout the day and across the lifecycle of its plants.[43] Based on the Azure IoT system with pH sensor devices, Costa Farms is now able to not only automatically measure pH levels, but dramatically increase its yield using fewer chemicals.

- **Advancing weed-whackers to spot and zap weeds more efficiently.** New technologies also create opportunities to kill weeds more accurately. Robotic weed-whackers with image recognition software can recognize weeds and zap them with a laser or apply a micro-dose of herbicide directly to a weed's leaf. These devices can cut herbicide use by as much as 99.99 percent.[44]

- **Crowdsourcing caustic critter solutions.** Software also enables new ways to tackle infestation problems. When some local farmers had lost up to 90 percent of their crops to fruit flies, Greenwood Orchards turned to Microsoft's cloud technology to fight the critters.[45] Using traps tied to GPS coordinates, they developed a crowdsourced application that created a community-wide infestation monitoring system to detect the early warning signs and enable early action to prevent devastating consequences.

> Each year, as much as 40 percent of the world's potential harvests are lost to damaging insects, weeds, and plant diseases.

Improving Food Safety and Logistics From Their Farm to Your Fork

Software is also vital to the process of getting fresh food to your table in a safe and traceable manner. Being able to monitor and track the food production process not only helps ensure food safety, but also can cut food waste. According to McKinsey, about a third of food produced is lost or wasted every year at a cost of $940 billion globally.[46] About 50 percent is wasted in the food distribution process alone.[47]

To get the freshest food to the right place at the right time, produce needs to be routed as efficiently as possible because every minute food is ripening, microbial populations may be growing. Software not only helps speed distribution and management of the entire supply chain, it also can play a critical role in the unfortunate event that contaminated food needs to be traced back to its source. By improving traceability, sophisticated software can now cut the costs of resolving a food recall in half[48] while building a level of trust in the food supply chain that was previously unattainable.

- **Tracking tomatoes from the field to your ketchup bottle.** Kagome, one of the largest tomato processors, uses IoT sensors and Microsoft's cloud to manage the entirety of its supply chain process — from field harvesting, to factory delivery, to in-plant processing and shipment to its customers. To improve food security, the software enables them to figure out where a tomato comes from, and where it ends up. The company calculated a return on investment of about 500 percent in the first season alone.[49]
- **Getting the right food to the right place at the right time.** Cargill, responsible for 25 percent of all US grain exports, turned to software from SAP to create a digital supply chain.[50] It not only helped Cargill improve transportation logistics and on-time delivery, it also helped reduce the cost of integrating plant systems by 70 percent.
- **Ensuring high-quality rice in every single bite.** And any time you thrust a fork into a pile of Uncle Ben's rice, you are looking at rice kernels that can be traced back through an entire global supply chain thanks to Microsoft's Azure cloud software.[51] Because Mars Food uses Transparency-One supply chain software to monitor its global food supply chain from the cloud, they are able to ensure quality products. The software not only tracks food supplies but also helps them ensure their rice comes from sustainable farms that use resources responsibly, pay farmers well, and have good working conditions on every farm.
- **Improving trust and transparency in the food you eat with a blockchain ecosystem.** Today, consumers often want to know everything possible about their food, like where it's from, how it was produced, and whether it's organic or sustainably grown. Similarly, food processors and sellers increasingly need to know everything about the food they use and have trust in the entirety of its food supply chain. To advance a global trusted holistic food supply chain, IBM has developed an innovative Food Trust, powered by their blockchain platform.[52] This network directly connects growers, processors, wholesalers, distributors, manufacturers, retailers, and others to enhance visibility and accountability in each step of the food supply. Importantly, it allows companies like Walmart to trace food throughout its entire journey in seconds, not weeks.

Improving the Vitality of Livestock

Livestock management is often a 24/7 endeavor. When livestock are fitted with sensors, farmers and ranchers can remotely monitor and manage the vitality of their livestock around the clock and across the farm — watching over the health, location, and well-being of every animal wearing a connected sensor. The data derived can lead to insights that produce better yields, increase survival rates, and improve milk output.

- **Supporting livestock vitality through real-time sensor monitoring.** Connected sensors enable ranchers to more quickly identify sick cattle that need to be pulled from the herd to prevent the spread of disease. Acoustic sensors that can recognize coughing are giving pig farmers an early warning for possible respiratory sickness. Accelerometers on a cow's tail can help predict when it is ready to breed, or send a farmer a text message when it goes into labor to give birth — helping improve chances of a live birth.[53] A pH sensor in a cow's stomach that only activates when it detects high acidity levels can be an early warning sign for SARA — a digestive disorder that reduces milk yields by three liters per cow per day and costs the US dairy industry as much as $1 billion a year.[54] A trial of these connected pH sensors showed an increase in production in 60 percent of farms, which could translate into a 10 percent increase in milk yield overall.[55]
- **Ensuring every cow counts.** SCR Dairy developed HealthyCow24, which combines Microsoft's Windows embedded software, with connected devices and its Azure cloud, to help farmers monitor their cows to help boost milk production, smooth the calving process, and ensure healthier cows.[56] The technology now connects about four million cows, enabling farmers to get real-time alerts on their smartphones.[57]

When livestock are fitted with sensors, farmers and ranchers can remotely monitor and manage the vitality of their livestock around the clock and across the farm — watching over the health, location, and well-being of every animal wearing a connected sensor.

Improving the Environment and Reducing Greenhouse Gas Emissions

Food production is responsible for the largest share of CO^2 emissions worldwide. A large part of this is caused by livestock, which are responsible for half of all greenhouse gas emissions — three times that of all transportation sources worldwide combined.[58] Reducing these emissions is a big challenge. Methane from livestock accounts for nearly 40 percent of all greenhouse gas emissions from agriculture.[59] Fortunately, farmers are breathing a little easier thanks to software and connected sensors that help cut livestock emissions by monitoring feeding and digestion to optimize their diet and potentially reduce emissions.

- **Cutting greenhouse gasses by minimizing its largest source.** New "clean cow" technologies like the wireless sensors from WellCow can help optimize the diet for cattle by remotely monitoring what they eat and how well they digest it to identify opportunities to reduce methane emissions.[60] USDA also has developed software called the Dairy Gas Emissions Model (DairyGEM) for estimating and reducing the emissions from these gas-passing cows.[61]

- **Reducing farm fuel use with digitally directed farm equipment.** Agricultural greenhouse gas emissions also emanate from using farm equipment. Using conventional methods, farmers use more than six gallons of diesel fuel per acre each year.[62] But now, with the advent of software-enabled GPS-guided farm equipment, farmers are able to cultivate the land more uniformly without passing over the same point multiple times. These tractors use 40 percent less fuel than conventional methods — meaning lower fuel costs and fewer greenhouse gas emissions.[63]

Growing Foods That Are More Nutritious and Sustainable

Americans face critical challenges related to the health of the food they eat, from diabetes, gluten intolerance, high cholesterol, and a growing obesity epidemic. When we can grow more nutritious foods and increase every American's access to fresh fruits and vegetables, it can save thousands of lives and billions of health care dollars in the process.

Cloud biology is a new field that combines AI, DNA data, machine learning, and analytics to reduce the time needed to identify new crop breeds that are more nutritious and sustainable. By moving tests from the lab to the cloud, it shrinks the time it takes to identify ideal genetic signatures from years to weeks which in turn can enable huge breakthroughs. For example, scientists use software to identify the genes necessary to help develop wheats and nuts that don't cause allergic reactions, soybeans that don't contain the unhealthy trans-fats that contribute to high cholesterol and heart disease, and biofortified foods that help prevent malnutrition in low-income communities. With the help of software, machines can drop bits of DNA into tubes that use enzymes — like a pair of tiny genetic scissors — to turn certain food traits on and off almost as easily as we turn on and off the lights. In other cases, scientists can use cloud software to model a plant's metabolism and identify the genes that could improve photosynthesis and crop growth. These software innovations could help increase plant diversity and empower farmers with fresh approaches for expanding what they can produce.

- **Developing more nutritious, delicious, and sustainable foods.** Startup Ginko BioWorks is a Boston-based organism design foundry that uses software, banks of robotic DNA synthesizers, and software-controlled molecular analysis robots to create a vast decisional database. The resulting data helps the company's software make increasingly accurate predictions about which biological parts work together to create certain compounds. These results in turn help scientists design better food for livestock, create better enzymes for turning milk into cheese, produce new yeasts for better beer, and identify new options for food sweeteners that may be healthier for consumers.[64]

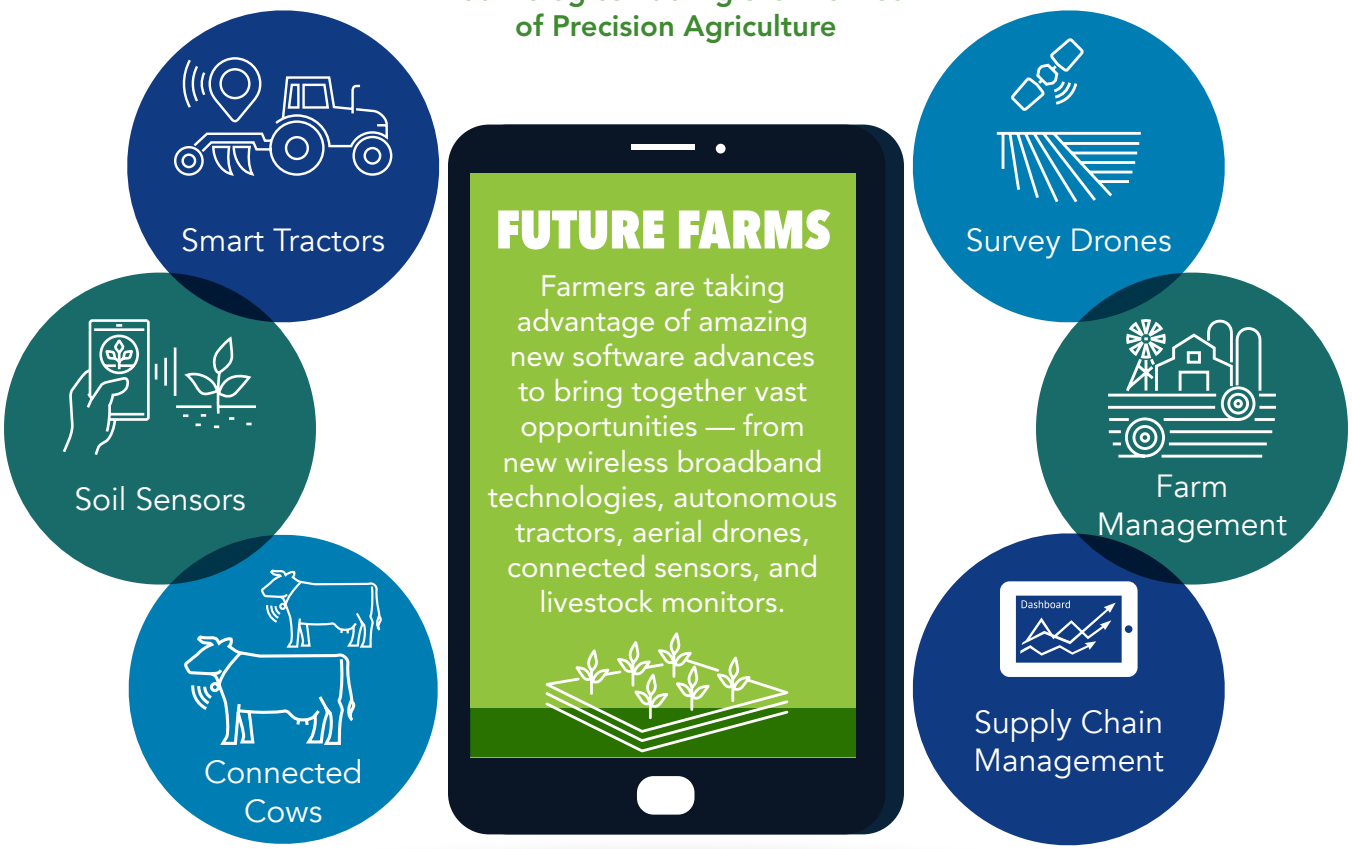
- **Moving plant research to the cloud.** Emerald Cloud Lab's web-based life sciences laboratory is cutting the cost and improving the efficiency of lab work by enabling researchers to run experiments in a centralized computer-controlled

Cloud biology is a new field that combines AI, DNA data, machine learning, and analytics to reduce the time needed to identify new crop breeds that are more nutritious and sustainable.

lab from anywhere in the world. Using machines that look like 3D printers but work more like a remote army of lab technicians pipetting drops of DNA, the service enables researchers to remotely order tests so they can focus on their research, without the grunt work of washing test tubes.[65] It's a lab in the cloud.

- **Opening the door to entirely new kinds of agriculturally based products and solutions.** Autodesk developed software that makes it easier for scientists to design, visualize, and simulate proteins in the cloud.[66] Its Genetic Constructor software helps with everything from high-level genome sketches to base-pair editing. Its Molecular Simulation software enables scientists at all levels to simulate molecular design, while its Wet Lab Accelerator software enables cloud biology as a sort of robotic lab assistant. It could open the door to entirely new kinds of agriculturally based products and solutions — like new kinds of biofuels and new ways to make insulin from plants.

Technologies Fueling the Promise of Precision Agriculture

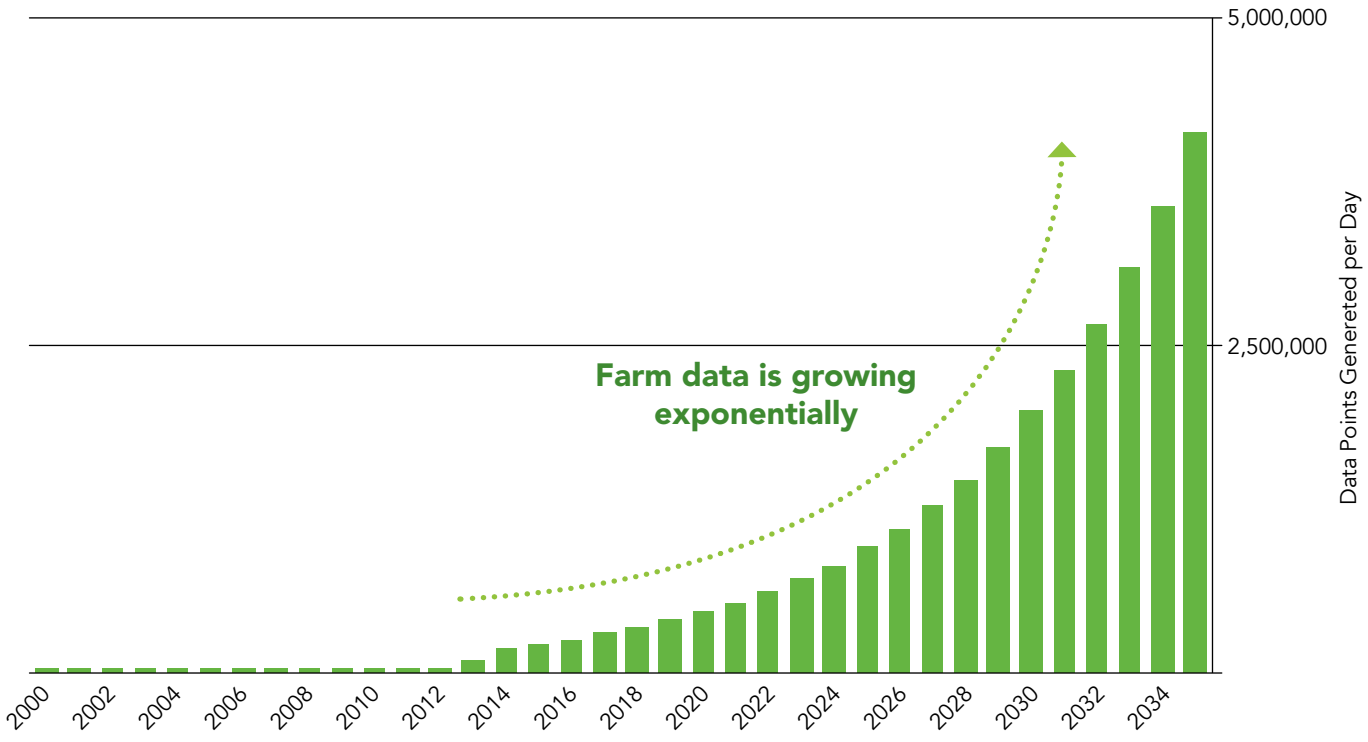


Farming Data: The Bigger the Data, the Greater the Yield

Today's farms generate lots of rich and varied data that must be harvested before it becomes useful. In 2014, the average farm produced just 190,000 data points per day. By 2050, a connected farm will be generating more than four million data points per day. As data grows exponentially, so does opportunity. The key challenge for data analysts is turning this deluge of information into actionable insights for farmers.

Farmers used to store their most precious resource in silos. Now they are storing their most precious data in the cloud. But when new farm equipment is introduced, the data might be siloed and stored for only one purpose. To enable precision opportunities, data needs to be stored in the cloud where it can be acted upon by software solutions to enable new insights, and accessed from the farmhouse, the office, or even a combine's cab.

Estimated Amount of Data Generated by the Average Connected Farm Per Day

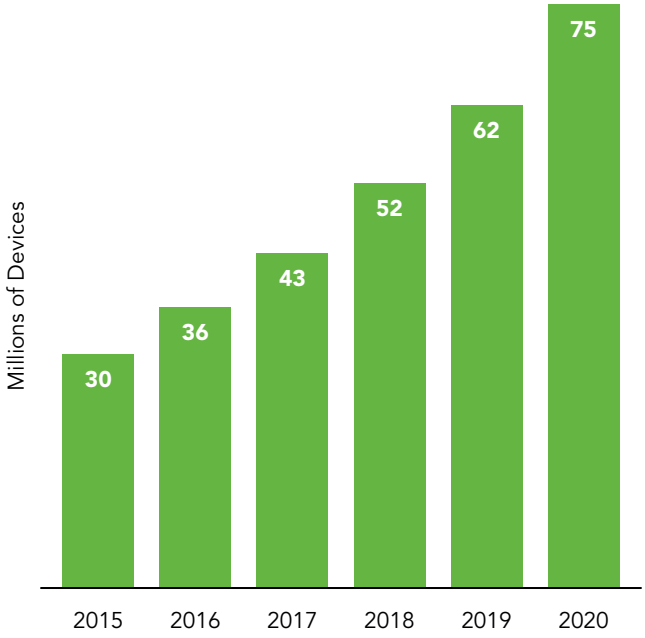


Source: Onfarm, BI Intelligence Estimates

Internet of Things: Sensing New Agricultural Opportunities

Some of the most powerful technologies enabling precision farming techniques today are software connected sensors that are transforming almost every aspect of farming operations. Wireless sensors can detect 26 different soil health parameters — from moisture, temperature, pH levels, aeration, and nutrient levels like nitrogen phosphate and potassium.[67] Other types of sensors are used with livestock to monitor key information that helps farmers improve healthy outcomes. These connected sensors are proving to be such a game changer that the number of connected agricultural devices is expected to grow orders of magnitude bigger — from 13 million at the end of 2014 to 225 million by 2024, and up to 2 billion by 2050.[68]

Connected Agriculture Devices Are Doubling



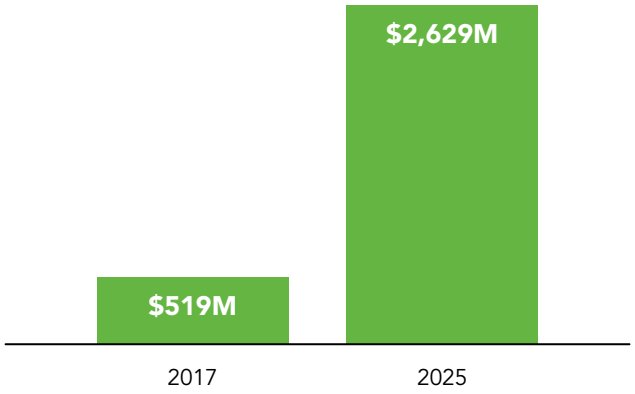
Source: Business Insider Intelligence Estimates

Artificial Intelligence: Creating Smarter Farming Solutions

To grow robust crops, farmers must constantly juggle a set of variables — soil moisture levels, looming weather, plant nutrition, and pest outbreaks — to calculate the exact cost of steps that can boost their bottom line. Now AI tools are performing calculations for the farmer with insights that simply could never have been calculated before.

One of the biggest AI applications that is helping farmers is hyper-local weather predictions. According to USDA, 90 percent of crop losses are caused by weather.[69] This crop damage can be reduced by an estimated 25 percent using predictive weather modeling and other precision agriculture techniques.[70] It helps ensure fewer crops are wasted and more food makes it to the table.

Artificial Intelligence in Agriculture
Growing 5 times larger by 2025



Source: Markets and Markets

AI in agriculture is turning out to be so powerful that market forecasters project the AI in the agriculture market to grow from $519 million in 2017 to $2.6 billion by 2025 — growing 22.5 percent per year.

These AI tools are being put to work today. For example, IBM's self-learning weather models are enabling farmers to take advantage of new kinds of hyper-local weather forecasts. When combined with IBM Watson's IoT platform, the system can analyze a variety of data like temperature, soil pH and other agricultural and environmental factors to give farmers insights that can help them make better decisions — and harvest greater yields.[71]

AI in agriculture is turning out to be so powerful that market forecasters project the AI in the agriculture market to grow from $519 million in 2017 to $2.6 billion by 2025 — growing 22.5 percent per year.[72]

Precision-Controlled Farm Equipment: Driving Efficiency in the Field

Forget self-driving cars; autonomous tractors are gaining traction and can already drive themselves through crop fields using GPS with less than an inch of error. These machines are enabled by Trimble, whose software allows highly accurate GPS-controlled navigation and steering systems for tractors.

Agricultural equipment manufacturers are embedding autonomous GPS navigation right into new farm equipment. John Deere estimates about two-thirds of large US farmers already use self-driving technology.[73] These tractors can be fitted with sensors that collect crop and soil data and can use variable-rate spreaders and sprayers that make sure fertilizers, herbicides, and pesticides are used in exactly the right amounts. They have found that software-enabled precision agriculture technology raises profitability per acre by $5 to $100 and increases overall productivity by 15 percent.[74]

Much of this machinery innovation has been made possible by software that has sped up agricultural machine design. For example, John Deere turned to Siemens software to enable faster design and virtual testing to improve the performance of new agricultural equipment.[75]

Agricultural Robots: Getting Precision Ag Rolling

Innovators are developing specialized AI-enabled robots that help farmers work more efficiently. These autonomous robots tend to the crops by seeding, weeding, fertilizing, and harvesting. Soil experts estimate large tractors and combines reduce field yield by up to 13 percent due to soil compaction, but a shift to smaller more autonomous robots can help boost yield and enable new precision.

- For example, the Lettuce Bot — a sort of Roomba for crops — uses a 3D camera mounted on a tractor and clever software processing to analyze real time images of lettuce crops to improve yields by precisely feeding each plant with the nutrients it needs to maximize output.[76]
- Similarly, Switzerland-based Ecorobotix has developed an ultra-light, solar-powered autonomous weeder that uses an AI-assisted camera to apply micro-doses of herbicide directly to a weed's leaves — cutting herbicide usage by 20 percent.[77]
- However, when some crops get tall, like corn, it can become a challenge to apply the right amounts of nutrients like nitrogen to the soil. Enter the cleverly named RowBot, which can navigate between rows of corn to keep nitrogen levels in sync with corn needs.[78]

> Innovators are developing specialized AI-enabled robots that help farmers work more efficiently.

Drones: Helping Farmers See Things More Clearly

With the help of autonomous drones, agricultural opportunity is looking up. For years, farmers have had to survey fields by foot. But now software-controlled drones are taking on tasks like field surveys to give farmers a more comprehensive vision of farming needs. With just a tap on a smartphone app, drones can create HD imagery, 3D maps, and multi-spectral imagery — allowing farmers to see their fields in ways beyond what a human eye can see. These drones can map weeds, yield, and soil variations from above to spot problems sooner. They produce a ton of data. In just one 160-acre field, a drone can take more than 150 high-resolution pictures, generating huge amounts of data that needs to be transmitted, processed, and correlated to identify new actionable insights.[79] As overhead imagery is fed into an AI engine, it can identify troubles like fungus growth in corn and soybean crops weeks before the naked eye detects it.[80] Being able to treat diseases early saves money and helps ensure greater yields.

Food for Thought: Four Key Recommendations to Enable Precision Farming Opportunities at Every Farm

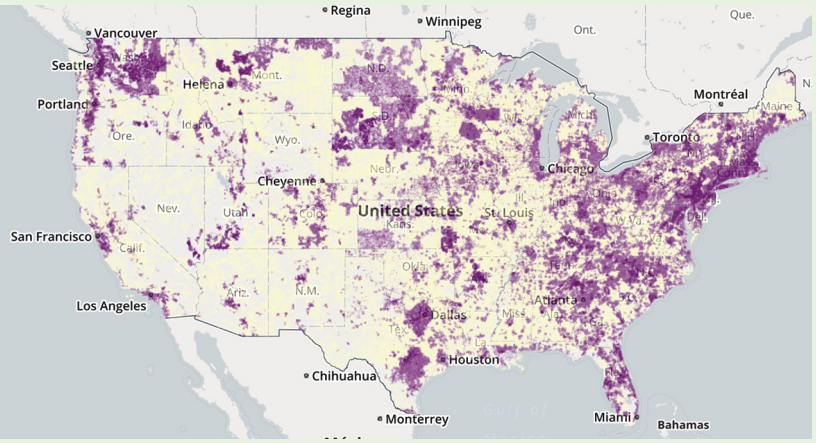
1. **Extend Precision Agricultural Opportunity Everywhere by Closing the Rural Broadband Gap**
2. **Enable Thousands of New Ag State Software Jobs by Closing the Farm State Software Skills Gap**
3. **Remove Barriers to Adoption by Fostering Farmer Trust by Modernizing Federal Data Policies**
4. **Enable Even Smarter and Bigger Agricultural Opportunities by Advancing a National AI Framework**

Although precision agriculture usage is growing rapidly, in 2015 precision agriculture technology was used on less than 20 percent of farmland.[81] Farmers may be unable to take advantage of the opportunities enabled by these technologies because they lack reliable broadband, don't have access to programmers who can customize solutions, want assurances that their data is private, and need access to continuously advancing smart AI technologies.

Extending precision agricultural opportunity everywhere by closing the rural broadband gap.

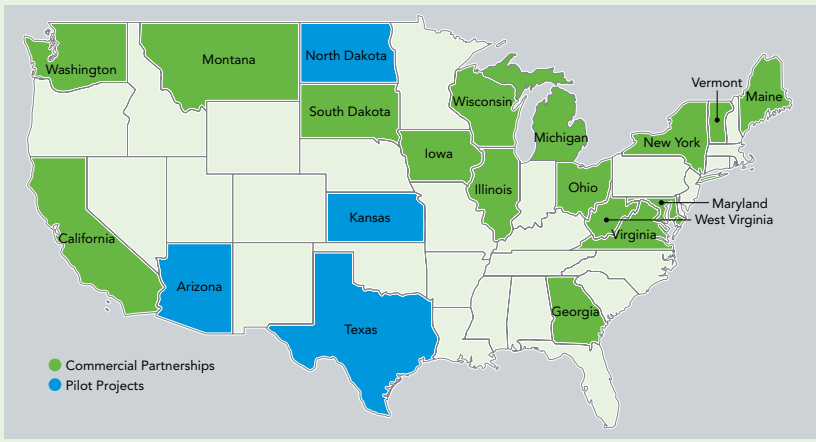
For farmers and ranchers, ubiquitous rural internet access has now become an agricultural accelerator and economic imperative. Broadband is not only essential for connecting the sensors, software, and clouds that enable precision farming techniques, but it also is vital for enabling farmers to search for new customers, find buyers, and identify the most affordable sources of seeds, fertilizers, and farm equipment.

Rural Broadband and the Digital Divide



This FCC map shows whether there are providers of fixed residential services of at least 25 Mbps/3 Mbps in a specific area. Yellow areas indicated areas that have no providers at 25Mbps/3Mbps.

TV White Spaces Pilot Project



An effort to use TV white spaces to close the rural broadband gap, the Microsoft Airband Initiative has projects in 16 states, and that number is expected to grow to 25 in 2019.

Unfortunately, rural Americans have been left behind in the broadband revolution where an estimated 19.4 million Americans live without access to high-speed broadband.[82] Making matters worse, the USDA reports that 29 percent of US farms have no access to the internet at all.[83] Without rural broadband, this digital divide means farmers lack the tools they need to take advantage of software-enabled precision farming technologies, and rural communities lack the tools they need to grow in a global economy.

Given the lack of farm access and the size of the precision agricultural opportunity, congressional leaders already have set a critical goal of achieving reliable internet service on 95 percent of farmland by 2025.[84] To address this, software innovators are advancing new rural broadband solutions using something called "TV White Spaces" that overcome the economics of distance that have long left rural communities digitally disconnected. The technology takes advantage of underused television spectrum to transmit data to places that have been left behind for too long.

The opportunity for rural America is one of the reasons why the Farm Bureaus in Montana, Oregon, South Dakota, and Wisconsin have all come together to support the deployment of this new wireless broadband technology.[85] Together with a group of more than 100 organizations, leaders are working with the Federal Communications Commission (FCC) and other policymakers to allocate enough unlicensed, low-band spectrum in every market to expand broadband connectivity via TV White Spaces — enabling broader precision agricultural opportunity everywhere.[86]

Enabling thousands of new ag state software jobs by closing the farm state software skills gap.

Software developers are the force multipliers when it comes to creating the breakthrough applications that will propel major agricultural advances in the years ahead. But many executives have come to understand that lack of access to software developer talent is one of the biggest potential threats to growth — bigger than even access to capital.[87] With nearly 200,000 software jobs expected to be created in the top 12 agriculture producing states by 2026, it's critical that these farm states have the developer skills necessary to fill these jobs.[88] Unfortunately, today there are already more than 500,000 unfilled computing jobs nationwide,[89] and the US Bureau of Labor Statistics

estimates that one million computer programming jobs in the United States will go unfilled by 2020.[90] To overcome this rural skills gap, we need to cultivate skilled coders who work in rural areas and can design and run the transformative software-enabled tools of tomorrow. That is why policymakers throughout the country need to make investments in computer science education to help prepare the next generation of software-literate workers by ensuring that computer science is taught in every high school.

Removing barriers to adoption by fostering farmer trust by modernizing federal data policies.

In order to advance precision farming adoption, it's critical that farmers have assurance that their data can be appropriately protected.[91] That's why modernizing federal data policies to ensure they are clear, effective, and predictable for farmers, innovators, and governments alike is critical to unlocking agricultural opportunity. Given that 9 out of 10 farmers use a smartphone in their combine,[92] they also need to trust that the information in their personal devices can be appropriately secured.

Enabling even smarter and bigger agricultural opportunities by advancing a national AI framework.

The smartest farming solutions today rely on AI to improve agricultural opportunity — from autonomously driving precision farm equipment, to hyper-localized weather forecasts, to systems that spot crop diseases in advance, to software that can project the perfect moment to maximize a harvest. Artificial intelligence is so critical that market forecasters project that AI solutions in agriculture will grow at a rate of 22.5 percent per year.[93] Despite that AI opportunities are growing at such a high rate, the United States has no federal policy toward AI or a strategy for advancing its trusted use. To address this, congressional leaders are looking to advance AI opportunities by setting up a process to develop forward-looking recommendations that can spur investment, empower the workforce, protect privacy, and ensure ethical behavior, among others.[94]

Conclusion

Today's precision agriculture advancements aren't just improving the way farmers grow, feed, harvest, and distribute food, they have the potential to boost yields, cut costs, and dramatically expand what the agricultural sector can achieve. With software innovations now firmly planted at the forefront of future farming opportunity, the key question is how quickly we can remove the barriers that prevent farmers from taking full advantage of these opportunities to accelerate agricultural opportunity all the way from the farm to the dinner table.

Endnotes

1 Mark W. Rosegrant et al., *Food Security in a World of Natural Resource Scarcity: The Role of Agricultural Technologies*, International Food Policy Research Institute (2014), available at http://www.ifpri.org/publication/food-security-world-natural-resource-scarcity-role-agricultural-technologies.

2 Aaron Tilley, *The Internet Versus the Great California Drought*, Forbes (July 20, 2015), available at https://www.forbes.com/sites/aarontilley/2015/07/01/the-internet-versus-the-great-california-drought/.

3 Sam Smith, *Here Come the Robots: Precision and Regenerative Farming*, The Futures Centre (April 12, 2018), available at https://thefuturescentre.org/articles/217999/here-come-robots-precision-and-regenerative-farming.

4 Rosegrant et al., *Food Security in a World of Natural Resource Scarcity*.

5 National Geographic, *Farming: There's an App for That* (June 5, 2018), available at https://www.nationalgeographic.com/environment/future-of-food/food-future-precision-agriculture/.

6 Michael Mandel and Elliot Long, *Iowa's App Economy*, Progressive Policy Institute (October 2017), available at http://www.progressivepolicy.org/wp-content/uploads/2017/10/PPI_Iowa_Apps_2017.pdf.

7 ERS/USDA and BLS long-term occupational projections (2016–2026) for software-related occupations. The job categories included the following OCC codes: 15-1121 Computer Systems Analysts; 15-1122 Information Security Analysts; 15-1131 Computer Programmers; 15-1132 Software Developers, Applications; 15-1133 Software Developers, Systems Software; 15-1134 Web Developers; 15-1141 Database Administrators; 15-1142 Network and Computer Systems Administrators; 15-1143 Computer Network Architects; 15-1151 Computer User Support Specialists; 15-1152 Computer Network Support Specialists; and 15-1199 Computer Occupations, All Other.

8 According to BLS data, the average American annual wage of $37,040 is less than half an average software application developer who earns on average $100,080. (BLS 2016 median annual wage (codes 15-1132 and 15-1133 versus 00-0000.) Even web developer jobs—a kind of software job that requires comparatively minimal skills—pay almost twice the national average.

9 Accenture, *Digital Agriculture: Improving Profitability*, available at https://www.accenture.com/us-en/insight-accenture-digital-agriculture-solutions.

10 USDA, *Farm Computer Usage and Ownership* (August 2017), available at http://usda.mannlib.cornell.edu/usda/current/FarmComp/FarmComp-08-18-2017_correction.pdf.

11 Jerry Revich et al., *Profiles in Innovation: Precision Farming: Cheating Malthus With Digital Agriculture*, Goldman Sachs Equity Research (July 13, 2016), available at https://docdrop.org/static/drop-pdf/GSR_agriculture-N1sH6.pdf.

12 United Nations, *World Must Sustainably Produce 70 Per Cent More Food by Mid-Century* (December 3, 2013), available at https://news.un.org/en/story/2013/12/456912.

13 Rosegrant et al., *Food Security in a World of Natural Resource Scarcity*.

14 Accenture, *The World of Agriculture Is About to Change* (July 28, 2017), available at https://innovation-awards.nl/en-us/articles/agriculture-is-about-to-change.

15 Scientific American, *How Fertilizers Harm Earth More Than Help Your Lawn*, available at https://www.scientificamerican.com/article/how-fertilizers-harm-earth/.

16 Smith, *Here Come the Robots*.

17 Tariq Khokhar, *Globally, 70% of Freshwater Is Used for Agriculture*, The World Bank (March 22, 2017), available at https://blogs.worldbank.org/opendata/chart-globally-70-freshwater-used-agriculture.

18 Mesfin M. Mekonnen and Arjen Y. Hoekstra, "Four Billion People Facing Severe Water Scarcity," *Science Advances* 2, no. 2 (February 12, 2016), available at http://advances.sciencemag.org/content/2/2/e1500323.

19 Tilley, *The Internet Versus the Great California Drought*.

20 FoodLogicIQ, *Track & Trace*, available at https://www.foodlogiq.com/solutions/traceability/.

21 Center for Science in the Public Interest, *Why Good Nutrition Is Important: Unhealthy Eating and Physical Inactivity Are Leading Causes of Death in the U.S.*, available at https://cspinet.org/eating-healthy/why-good-nutrition-important.

22 World Health Organization, *Promoting Fruit and Vegetable Consumption Around the World*, available at http://www.who.int/dietphysicalactivity/fruit/en/index2.html.

23 Angela Huang, *Transforming the Agricultural Industry*, IBM: Internet of Things Blog (August 9, 2016), available at https://www.ibm.com/blogs/internet-of-things/agricultural-industry/.

24 Julia Chen Davidson, *Big Data + Big Agriculture = Big Opportunities*, IBM Consumer Products Industry Blog (January 8, 2014), available at https://www.ibm.com/blogs/insights-on-business/consumer-products/big-data-big-agriculture-big-opportunities/.

25 Revich et al., *Profiles in Innovation: Precision Farming*, p. 14.

26 Microsoft, *FarmBeats* (Infographic), available at http://download.microsoft.com/download/C/E/A/CEACFE2D-CF21-4581-8F68-BDD0A6CEC4F9/FarmBeats_Infographic_Web.pdf.

27 "TV Dinners: Unused TV Spectrum and Drones Could Help Make Smart Farms a Reality," *The Economist* (September 17, 2016), available at https://www.economist.com/science-and-technology/2016/09/17/tv-dinners.

28 Tariq Khokhar, *Globally, 70% of Freshwater Is Used for Agriculture*.

29 Romit Atta, *Farming 2.0: How Does IoT Help Agriculture Domain?* NetManias (September 19, 2017), available at https://netmanias.com/en/post/blog/12735/iot/farming-2-0-how-does-iot-help-agriculture-domain.

30 Tilley, *The Internet Versus the Great California Drought*.

31 Trimble, *Precision Irrigation*, available at https://agriculture.trimble.com/precision-ag/solutions/irrigation/.

32 Trimble, *Precision Agriculture Field Solutions*, available at https://agriculture.trimble.com/precision-ag/.

33 "Technology Quarterly: The Future of Agriculture: Factory Fresh," *The Economist*, available at https://www.economist.com/technology-quarterly/2016-06-09/factory-fresh.

34 Ibid.

35 Laurie Bedord, "Irrigation, Innovation Saving Water in Kansas," *Successful Farming* (April 17, 2017), available at https://www.agriculture.com/machinery/irrigation-equipment/irrigation-innovation-saving-water-in-kansas.

[36] *E. & J. Gallo Winery Is Working With Watson to Develop an Intelligent Irrigation System That Increases the Quality of Its Grapes*, IBM: Watson, available at https://www.ibm.com/watson/stories/ejgallo/.

[37] *EZ Farm: Uses the Internet of Things to Improve Food Security in Africa*, IBM, available at https://www.ibm.com/case-studies/t869341z93257n45.

[38] Food and Agriculture Organization (FAO) of the United Nations, *Keeping Plant Pests and Diseases at Bay: Experts Focus on Global Measures*, available at http://www.fao.org/news/story/en/item/280489/icode/. FAO estimates that between 20 and 40 percent of global crop yields are reduced each year due to the damage wrought by plant pests and diseases.

[39] Scientific American, *How Fertilizers Harm Earth More Than Help Your Lawn*.

[40] Revich et al., *Profiles in Innovation: Precision Farming*, p. 8.

[41] Scientific American, *How Dangerous Is Pesticide Drift?* available at https://www.scientificamerican.com/article/pesticide-drift/.

[42] Trimble, *Field-IQ Crop Input Control System*, available at https://agriculture.trimble.com/precision-ag/products/field-iq/.

[43] *Farming for Data: The Global Agriculture Industry's Tech Makeover*, Microsoft Industry Blogs (December 6, 2017), available at https://cloudblogs.microsoft.com/industry-blog/industry/manufacturing/farming-for-data-the-global-agriculture-industrys-tech-makeover/.

[44] Smith, *Here Come the Robots*.

[45] Isabel Boniface, *Crowdsourced Data and Azure Squash Fruit Fly Marauders*, Microsoft (March 14, 2017), available at https://news.microsoft.com/en-au/features/crowdsourced-data-and-azure-squash-fruit-fly-marauders/.

[46] Clarisse Magnin, *How Big Data Will Revolutionize the Global Food Chain*, McKinsey & Company (August 2016), available at https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/how-big-data-will-revolutionize-the-global-food-chain.

[47] Huang, *Transforming the Agricultural Industry*.

[48] FoodLogicIQ, *Track & Trace*.

[49] *Farming for Data: The Global Agriculture Industry's Tech Makeover*.

[50] *Cargill: How Do You Create a Digital Supply Chain That Feeds the World?* SAP, available at https://www.sap.com/documents/2017/10/4286c97c-d87c-0010-82c7-eda71af511fa.html.

[51] *Mars Food Uses the Cloud to Track Rice From Farm to Fork*, Microsoft: Customer Stories (June 27, 2018), available at https://customers.microsoft.com/en-us/story/mars-food-consumer-goods-azure.

[52] *IBM Food Trust: Creating a Food Ecosystem Built on Trust and Transparency*, IBM: Blockchain, available at https://www.ibm.com/blockchain/solutions/food-trust.

[53] The Moocall: Wireless Calving Alert Sensors can detect when a cow is going into active labor. It straps to the tail, where it can monitor movement for the patterns of activity that mean a calf is on the way. Then Moocall uses the 3G mobile network to send a text alert to the farmer, who has about an hour to prepare for the arrival of the latest addition to the herd. See https://moocall.com.

[54] *Sub-Acute Ruminal Acidosis (SARA) in Dairy Cows* (Fact Sheet), available at http://www.omafra.gov.on.ca/english/livestock/dairy/facts/03-031.htm.

[55] *Precision Livestock*, Nesta, available at https://www.nesta.org.uk/feature/precision-agriculture/precision-livestock/.

[56] Lorence Heikell, Connected Cows Help Farms Keep Up With the Herd, Microsoft (August 17, 2015), https://news.microsoft.com/features/connected-cows-help-farms-keep-up-with-the-herd/.

[57] HealthyCow24, available at http://www.scrdairy.com/cow-intelligence/hc24-solution.html and *Farming for Data: The Global Agriculture Industry's Tech Makeover*, Microsoft Blog (December 7, 2017), available at https://cloudblogs.microsoft.com/industry-blog/industry/manufacturing/farming-for-data-the-global-agriculture-industrys-tech-makeover/.

[58] Accenture, *The World of Agriculture Is About to Change*.

[59] Maanvi Singh, "NPR: Gassy Cows Are Warming the Planet, and They're Here to Stay," NPR (April 12, 2014), available at https://www.npr.org/sections/thesalt/2014/04/11/301794415/gassy-cows-are-warming-the-planet-and-theyre-here-to-stay.

[60] WellCow, available at http://wellcow.co.uk/.

[61] USDA Dairy Gas Emissions Model, available at https://www.ars.usda.gov/northeast-area/up-pa/pswmru/docs/dairy-gas-emissions-model/.

[62] Elizabeth Creech, *Saving Money, Time and Soil: The Economics of No-Till Farming*, U.S. Department of Agriculture (November 30, 2017), available at https://www.usda.gov/media/blog/2017/11/30/saving-money-time-and-soil-economics-no-till-farming.

[63] *Smart Farming: The New Green Revolution*, SDSN Youth (September 10, 2017), available at http://sdsnyouth.org/food-and-youth-stories/2017/9/10/smart-farming-the-new-green-revolution.

[64] Elizabeth Stinson, "Move Over, Jony Ive—Biologists Are the Next Rock Star Designers," *Wired* (November 18, 2015), available at https://www.wired.com/2015/11/move-over-jony-ivebiologists-are-the-next-rock-star-designers/.

[65] The Emerald Cloud Lab, available at https://www.emeraldcloudlab.com/.

[66] Autodesk Life Science, available at https://autodeskresearch.com/groups/lifesciences.

[67] Chris Albrecht, *Teralytic Sensors Help Farmers Manage Their Fertilizing*, The Spoon (February 28, 2018), https://thespoon.tech/teralytic-sensors-help-farmers-manage-their-fertilizing/.

[68] *Agricultural IoT Will See a Very Rapid Growth Over the Next 10 Years*, Gartner (January 12, 2016), available at https://machinaresearch.com/news/agricultural-iot-will-see-a-very-rapid-growth-over-the-next-10-years/.

[69] Lloyd Treinish, "Precision Farming Gains Global Foothold (Op-Ed)," *LiveScience* (June 12, 2013), available at https://www.livescience.com/37400-smart-farming.html.

[70] Huang, *Transforming the Agricultural Industry*.

[71] IBM, *Let's Put Smart to Work* (Video), available at https://www.ibm.com/thought-leadership/smart/.

[72] Markets and Markets, *AI in Agriculture Market by Technology (Machine Learning, Computer Vision, Predictive Analytics), Offering, Application (Precision Farming, Drone Analytics, Agriculture Robots, Livestock Monitoring), Offering, and Geography - Global Forecast to 2025* (December 2017), available at https://www.marketsandmarkets.com/Market-Reports/ai-in-agriculture-market-159957009.html.

[73] Shara Tibken, "How Today's Farmers Got a Head-Start on Tomorrow's Tech," cNet (July 5, 2016), available at https://www.cnet.com/news/how-todays-farmers-got-a-head-start-on-tomorrows-tech-self-driving-vehicles-gps-mapping-apps/.

[74] Jeff Hawn, *IoT, Wireless Tech Set to Revolutionize Farming*, RCR Wireless (October 8, 2015), available at http://www.rcrwireless.com/20151008/internet-of-things/iot-wireless-set-to-revolutionize-farming-tag15.

[75] Siemans, *Agricultural Machine Design*, available at https://solidedge.siemens.com/en/industries/agricultural-machinery/ and Siemans, *Case Study: Agricultural Machinery Manufacturer Uses LMS Virtual.Lab to Increase Endurance Simulations*, available at https://www.plm.automation.siemens.com/en/about_us/success/case_study.cfm?Component=222942.

[76] Katie Fehrenbacher, "The Startup Behind the Lettuce Robot Has a New 3D Crop Scanner," *Fortune* (June 3, 2015), available at http://fortune.com/2015/06/03/3d-crop-scanner/.

[77] Smith, *Here Come the Robots*.

[78] RowBot, available at https://www.rowbot.com/.

[79] CoBank, *Farmers Harvest Gigabytes With Broadband and Wireless Technology* (March 2016), available at https://www.cobank.com/-/media/files/ked/communications/farmers-harvest-gigabytes-report--mar-2016.pdf.

[80] Matt McFarland "Farmers Spot Diseased Crops Faster With Artificial Intelligence," CNN (December 14, 2017), available at http://money.cnn.com/2017/12/14/technology/corn-soybean-ai-farming/index.html.

[81] Accenture, *Digital Agriculture: Improving Profitability*.

[82] Federal Communications Commission, *Broadband Progress Report*, available at https://www.fcc.gov/reports-research/maps/bpr-2016-fixed-25mbps-3mbps-technology/.

[83] USDA, *Farm Computer Usage and Ownership*.

[84] Elizabeth Meyer, *'Precision Agricultural' Broadband Bill Advances in U.S. House*, Government Technology (July 27, 2018), available at http://www.govtech.com/network/Precision-Agricultural-Broadband-Bill-Advances-in-US-House.html.

[85] John Youngberg, Barry Bushue, Scott VanderWal, and James Holte, *Opinion: Innovative Technologies to Enable Precision Agriculture Tools*, AgriPulse, available at https://www.agri-pulse.com/articles/11086-opinion-innovative-technologies-to-enable-precision-agriculture-tools.

[86] Zachary Cikanek, *Connect Americans Now Reaches 100 Members*, Press Release, Connect America Now (March 15, 2018), available at https://connectamericansnow.com/connect-americans-now-reaches-100-members/.

[87] *The Developer Coefficient: Software Engineering Efficiency and Its $3 Trillion Impact on Global GDP* (September 2018), available at https://stripe.com/files/reports/the-developer-coefficient.pdf. Collectively, developers have the ability to raise global GDP by $3 trillion over the next 10 years. Access to developers is a bigger constraint than access to capital.

[88] ERS/USDA and BLS long-term occupational projections (2016–2026) for software-related occupations. The job categories included here include the following OCC codes: 15-1121 Computer Systems Analysts; 15-1122 Information Security Analysts; 15-1131 Computer Programmers; 15-1132 Software Developers, Applications; 15-1133 Software Developers, Systems Software; 15-1134 Web Developers; 15-1141 Database Administrators; 15-1142 Network and Computer Systems Administrators; 15-1143 Computer Network Architects; 15-1151 Computer User Support Specialists; 15-1152 Computer Network Support Specialists; and 15-1199 Computer Occupations, All Other.

[89] According to https://code.org/.

[90] Tom Kalil and Farnam Jahanian, "Computer Science Is for Everyone!" The White House (December 11, 2013), available at https://obamawhitehouse.archives.gov/blog/2013/12/11/computer-science-everyone.

[91] America Farm Bureau, *American Farm Bureau Survey Shows Big Data Use Increasing, Big Questions Remain* (October 21, 2014), available at https://www.fb.org/newsroom/american-farm-bureau-survey-shows-big-data-use-increasing-big-questions-rem.

[92] John Walter, "There's an Ag App for That," *Successful Farming* (November 16, 2016), available at https://www.agriculture.com/technology/crop-management/there-s-an-ag-app-for-that.

[93] Markets and Markets, *AI in Agriculture Market by Technology*.

[94] Congressional Artificial Intelligence *Caucus, Cantwell, Young, Markey, Delaney & Olson Introduce Bill to Further Understand and Promote Development of Artificial Intelligence, Drive Economic Opportunity* (December 12, 2017), available at https://artificialintelligencecaucus-delaney.house.gov/media-center/press-releases/future-of-ai-act.

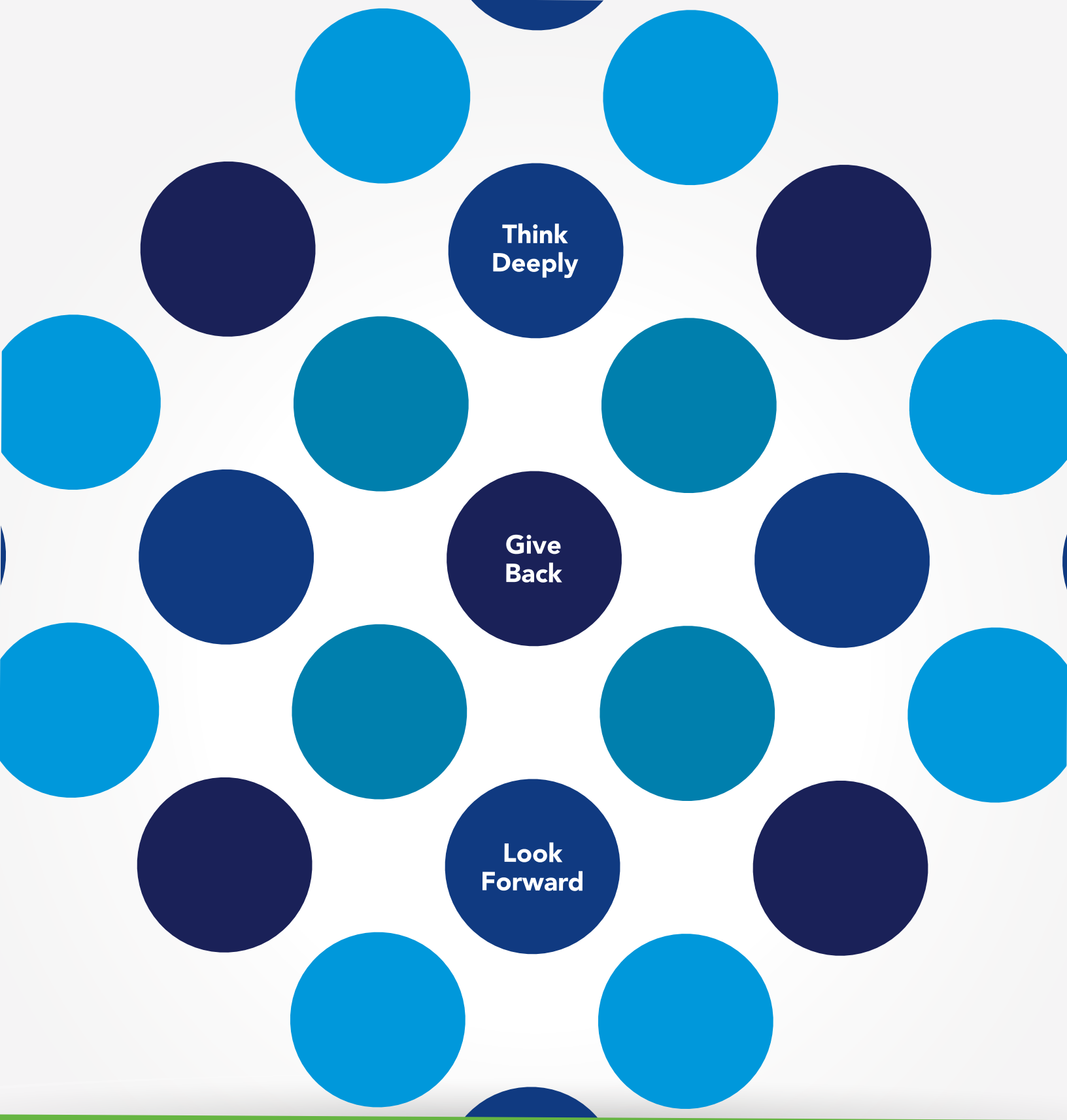
software.org
BSA Foundation

20 F Street, NW, Suite 800 Washington, DC 20001
202 872 5500 **www.software.org**


software.org/facebook


software.org/twitter


software.org/linkedin



software.org
BSA Foundation