



Digital Transformation NETWORK

An Initiative of BSA | The Software Alliance



AI in Agriculture

From Farm to Fork: Agriculture's AI Transformation

Around 11,000 years ago,¹ humans made the transition from hunting and foraging to farming land and raising animals. Earth's population has steadily expanded ever since. The UN predicts a global population of 9.7 billion by 2050,² which puts global food supplies under unprecedented strain.

The history of human growth is inseparable from advances in farming. From irrigation, iron tools, and ploughs, to crop rotation, fertilizers, and pesticides, innovation has supported global agriculture. Even as the amount of land, labor, and other inputs used in farming declined, total US farm output nearly tripled between 1948 and 2021, according to the USDA.³ Artificial Intelligence (AI) and the widespread use of digital tools is the next step in this journey.

This transformation is urgently needed. Earth needs more food—and more sustainable production methods. To achieve the Zero Hunger target while simultaneously keeping agricultural emissions on track to reach the Paris Agreement targets, average global agricultural productivity would need to increase by 28% over the next decade. This is more than triple the increase recorded in the last decade, according to the OECD-FAO Agricultural Outlook to 2031.⁴

This report explores how AI is already helping farmers grow safe, nutritious, sustainable food for the world's growing population—and what comes next. An overview of the value added by AI and real-world BSA projects is divided into three sections:

SECTION 1 Enhancing Sustainability

SECTION 2 Improving Systems

SECTION 3 Managing Future Needs

These challenges can only be overcome by all stakeholders working together. AI and cloud providers, farmers, government, and academia all have a role to play in ensuring global food supplies are secure, safe, and sustainable.

How do farmers worldwide grow more with less? By using AI and digital tools to enable change. This revolution is already underway: in 2019, Software.org; the BSA Foundation wrote about [how America's agriculture sector was using AI](#),⁵ data analysis, cloud computing, and Internet of Things (IoT) devices.

[AI potato sorters](#)⁶ and [autonomous tractors](#)⁷ have been helping get food to our tables for years. Take-up of technologies such as these is reaching an inflection point, where these technologies are available to smaller farmers, and countries across the global South.

The next wave of change will transform food systems entirely. Alternative proteins, including plant, insect, and fermentation-based alternatives to meat, eggs, dairy, and seafood, will play a vital role in feeding a hungry planet. Urban areas will take farming out of the fields entirely, with the rise of vertical farms. These new horizons require strong digital foundations, including using AI.

In the United States, AI is currently making a difference addressing labor shortages, combating declining yields and soil depletion, and improving resilience in an era of climate change. Some of the issues Software.org flagged in 2018 have seen significant progress. President Biden's Executive Order on AI goes a long way toward creating a national framework, which was previously lacking.

In 2022, Congress allocated \$65 billion in the Infrastructure Investment and Jobs Act to promote [broadband deployment in underserved areas](#).⁸ This is essential: as the Farm Bureau notes, techniques that maximize yield require data collection and analysis [both on-site and in the cloud](#)⁹—impossible without broadband.

Worldwide, farmers face the threat of climate change. In Texas, 2022 was one of the driest years on record, and the [Texas Department of Agriculture identified climate change as a potential threat to the state's food supply](#).¹⁰ Last year, Europe experienced its worst [summer drought](#)¹¹ in 500 years, leading to high costs and poor harvests.

AI-powered weather prediction can help farmers prepare for these challenging times, as well as mitigating the sector's role in causing them. Soil is the planet's second largest active pool of carbon after the oceans: better farming techniques can help keep it there.

Currently, more than one-third of global greenhouse gas emissions caused by human activity can be attributed to the way we produce, process, and package food, [according to the UN](#).¹² AI can make a huge difference to farmers' sustainability credentials, enabling them to do everything from use less water to measure the amount of carbon sequestered in the soil.

Governments are on board with change. The current US Farm Bill has been extended to the end of 2024; the USDA's National Institute of Food and Agriculture has already set out plans to harness the power of AI in [applications throughout agriculture and the food supply chain](#).¹³ The European Commission's Farm 2 Fork Strategy is at the heart of Europe's Green Deal.

SECTION 1

Enhancing Sustainability

Farms of every size, every type worldwide, need to produce more, using fewer resources. That requires measuring the current state of play, long- and short-term forecasting, and helping farmers make the right decisions.

AI can help farmers make better decisions at every stage. “The soil is not getting any richer; the water levels are receding; there is climate change—these make the farmers’ life much harder,” says [Microsoft’s Chief Technology Officer for Agri-Food, Ranveer Chandra](#).¹⁴ “One approach that can help is that of data-driven agriculture, where our goal is not to replace the farmer but to augment the farmer’s knowledge with data and AI.”

Soil sensors feed data to cloud-based systems, while data from overhead satellites is wrapped in for a fuller picture of the optimal moment to put seeds in the ground. Smart sensors placed in the soil, in drones, and in farm equipment such as harvesters and tractors can give granular details our ancestors could only dream of. Once data is collected, it can be analyzed.

The most basic AI models use pattern recognition but use huge data pools a human could never process to make more accurate forecasts. All this facilitates using the right amount of water, seeds, and pesticides at the right time—thus saving resources. The more advanced waves of AI go beyond this to take a longer-term view of farming practices that benefit not just the farmer and their customers, but the whole planet.

Industry, government, and academia all recognize the importance of making farming more sustainable. Scientists with the USDA Agricultural Research Service’s (ARS) Western Human Nutrition Research Center (WHNRC), at the University of California–Davis, have joined forces with more than 40 researchers from six organizations to form an institute that will use AI to create the next-generation food system. The project is funded by a \$20 million grant from USDA’s National Institute of Food and Agriculture.

The institute’s goals include using molecular breeding to improve crop yield, quality, and disease resistance; using AI applications and other technology, such as sensing platforms and robotics, to reduce resource use; enhancing food safety; and developing tools for consumers to make personalized health decisions.

AI is also a useful tool for measuring sustainability in these stages of food production. “Food miles” is a broadly understood concept, but what about the miles traveled by the raw ingredients? The methane released by the cows in the dairy ingredients? Producers are using AI and big data during product formulation so consumers can know the environmental footprint before new foods hit the shelves. Solutions such as [HowGood’s Latis platform](#)¹⁵ enable food companies to more easily report on emissions, reduce carbon footprints, and make verified sustainability claims—in turn giving the consumer power to make more sustainable decisions.

DX AT
WORK**DX at Work: (Less) Water Into Wine**

With more than 80 years' experience farming in California, E. & J. Gallo Winery understands the importance of water efficiency. The winery recently discovered that while some vines are thirstier than others, the existing irrigation system could not target sections smaller than 10 acres and manual watering required too much work to be feasible.

To help improve water efficiency, [E. & J. Gallo Winery used IBM Cloud™ to create a bespoke¹⁶ solution](#) that ingests data from weather forecasts, satellite imagery, and water lines wrapped with sensors that measure vine stress. This data is collected and used to create recommended watering instructions based on the needs of each vine. Next, water is delivered through a new, more-targeted irrigation system to help grapes ripen in sync and with improved quality. Since implementation, E. & J. Gallo Winery has increased yields by 26 percent, improved grape quality by 50 percent and reduced water usage for crop irrigation by 16 percent.

DX AT
WORK**DX at Work: Disparate Data, Shepherded by AI**

Founded in the 1860s, Germany's Bayer has been helping farmers grow crops more effectively ever since. They have access to data from satellites, sensors, and drones that generate hundreds of variables and attributes, but until recently, it's been difficult and expensive to turn that information into insights because these systems don't talk to each other.

AI changes this: machines can assess the data and see patterns at a scale people simply can't. They turned to Microsoft and built Bayer AgPowered Services on top of the [Microsoft Azure Data Manager for Agriculture¹⁷](#) platform. "Only innovation can ensure global food security while protecting the planet," said Dr. Robert Reiter, Head of R&D for Bayer's Crop Science Division. "Customers can use the infrastructure and capabilities to build their own digital solutions and products on top of the most robust collection of ag data in the world."

DX AT WORK



DX at Work: Business Needs Behind the Seeds

KWS SAAT SE is based in Einbeck, Germany, and dates to 1856. The world's fourth largest producer of seeds for sugar beetroot, cereals, corn, and rapeseed, it is a pioneer of 21st century agriculture, with data being the main "fertilizer." Camera drones, big data, and AI determine which breeds of seeds have the greatest potential; they also offer customers powerful precision-farming tools to analyze sowing and harvesting.

To facilitate this, KWS needs to manage the flood of data that is being generated in its global organization spread across 70 countries. In its centralized Shared Service Centre in Berlin, it brings together all administrative tasks of all business units worldwide. KWS relies on **Adobe** Document Cloud and a [customized framework agreement](#)¹⁸ to help make this major digital transformation endeavor a success.

DX AT WORK

DX at Work: Big Data for Texas Smallholders

As America's largest comprehensive agriculture program, [Texas A&M AgriLife](#)¹⁹ brings together a college and four state agencies focused on agriculture and life sciences. They worked with **IBM** through the IBM Sustainability Accelerator, a *pro bono* social impact program, to develop a tool that recommends when, and how much, farmers in arid regions should water their crops.

The result, [Liquid Prep](#)²⁰ is an end-to-end IoT and cloud solution for farmers looking to optimize their water usage. The result, Liquid Prep is an end-to-end IoT and cloud solution for farmers looking to optimize their water usage. It only requires an IoT soil sensor device with near field communication (NFC) capabilities, and a basic mobile phone that can connect to the cloud. A large focus is empowering farmers who are new to tech. The result is a reduction in input costs, less water used, improved yields, and a reduction of polluting runoff.

SECTION 2

Improving Systems

Farming is more of a vocation than a job. There is a task for every season, and plants and animals have needs that vary every minute of every day. AI can facilitate this repetitive but essential work, with everything from customized irrigation plans for plants, to autonomous drones that can spot and remove weeds, with minimal human intervention.

Take the so-called “Internet of cows” in India, where radio frequency identification (RFID) chips can be implanted on cattle to mine data on vaccination, feed, weather, and health, and predict and improve the yield of milk and milk fat. A basic mobile phone can receive this data, improving yields and revenue, reducing water consumption, and [transforming animal husbandry](#).²¹

At the other extreme, [so-called mega-farms could not exist](#)²² without digital technologies. Data-driven farming means digital information streams are a commodity, just like soil or water. Reliable data is essential as countries consider dramatic measures to [meet carbon reduction goals](#):²³ in Ireland, for example, the government has floated proposals to cull almost 200,000 dairy cows over the next three years. Long-term behavioral change on farms is important to promote practices such as soil carbon sequestration, a process in which CO₂ is removed from the atmosphere and stored in the soil carbon pool—and which is measured by probing the soil.

However, farmers’ main business should be farming, not data management. Legislators need to carefully craft laws and regulations on data protection, privacy, and cybersecurity, so farmers can be confident their proprietary data is secure.

Once food is grown or farmed, it needs to be harvested and distributed. Consumers know all about the benefits of freshness: nobody wants a chicken that has spent too long in the supply chain, or peaches picked too late. AI can help humans when time is crucial, by sorting, grading and assessing fresh produce.

The Department of Agriculture has prepared an inventory of its [AI use cases](#).²⁴ BSA members are already helping farmers use AI to grow their crops, harvest them at the optimal moment, and maintain freshness on their journey to consumers.

DX AT WORK

DX at Work: A Growing Role for Data

Fifth-generation farmer Andrew Nelson grows wheat, barley, and lentils in eastern Washington. Sensors in the soil, drones in the sky, and satellites in space provide information about his farm at distinct points, every day, all year long. He uses [Microsoft's Project FarmVibes](#) to turn agricultural data into action that can help boost yields and cut costs.²⁵

FarmVibes.AI algorithms, which run on Microsoft Azure, predict the ideal amounts of fertilizer and herbicide Nelson should use and where to apply them; forecast temperatures and wind speeds across his fields, informing when and where he plants and sprays; determine the ideal depth to plant seeds based on soil moisture; and tell him how different crops and practices can keep carbon sequestered in his soil.

For example, the first year Nelson used data to guide his spraying, the amount he saved was exactly the amount he earned. Earlier this spring, he applied the approach to one-third of his fields and saved nearly 35 percent on one of his most-used chemicals. After the fall harvest, he estimates saving an additional 40 percent.

DX AT WORK



DX at Work: A Cup of Joe That Starts With AI

Colombia's coffee industry accounts for 25 percent of the agricultural sector's contribution to GDP and generates about two million jobs. In Manizales, an area many connoisseurs say produces the best coffee in the world, Juan David Hurtado is the founder and manager of Blue Bird Coffee. With a background in engineering, he wondered if methods from the construction industry could boost his agriculture business.

"I relied on things like machine learning and business intelligence," Hurtado says. "They basically gather data, turn it into information, and then transform it into knowledge." For more than 40 years, Hurtado's father documented all of the farm's data using pen and paper. [His son turned to Autodesk Revit to survey the 18-acre property](#),²⁶ identifying the altitude of each zone and how many hours of sun and shade they get.

By combining databases, it's possible to determine whether coffee that has a better flavor was harvested in a batch that had less shade or some other factor. Revit can identify the best places to build certain projects: For example, there are spots where much more sun is needed for drying the coffee beans, which is one of the production phases that characterizes Colombian coffee.

DX AT
WORK**DX at Work: Helping Heifers in Heat**

Heifers—young cows—are a large economic investment for dairies. [Academics at Penn State](#)²⁷ writing about the use cases for AI in dairy farming note that replacement heifers who calve later than 23–24 months of age can impact economic success for a dairy. Missing just one heat cycle can easily put dairy producers behind schedule. However, AI can help farmers identify when a cow is ready to get pregnant, have a calf, and therefore produce milk.

Producers can place wearable sensors on their heifers to passively observe behaviors that show the cow is fertile. So-called estrus behaviors can include evidence of mounting another heifer or standing to be mounted (recorded as increased head or neck movements by the sensor), or an increased overall activity index relative to that heifer’s behavioral baseline.

DX AT
WORK**ORACLE®****DX at Work: Identifying Threats at Leaf Level**

AgroScout is taking on a massive, ongoing computing challenge. They scan millions of images from farmers’ fields and decide if a given leaf is healthy. If it’s not, machine-learning algorithms built determine whether the culprit is one of the diseases or pests it knows or if it needs to identify the traits of a new threat.

[AgroScout CEO Simcha Shore](#) turned to [Oracle Cloud](#)²⁸ to develop and run the system’s applications and algorithms. For its application to collect, manage, and upload images to the cloud, AgroScout uses Oracle Cloud Native Services. AgroScout’s machine learning relies on Oracle Cloud Infrastructure’s GPU instances, providing the speed and performance that machine-learning workloads demand. “We do the magic,” says Shore. “Because the AI is looking at those images like a person would, bringing that technology to every farmer.”

DX AT WORK

salesforce

DX at Work: More in Store

Business experts are always telling people not to keep things in silos...but Ag Growth International (AGI) helps farmers do just that. They provide customized engineering solutions to store and deliver the world's grain, fertilizer, seed, feed, and food supplies. With strong face-to-face relationships with farmers at the heart of their business, managing growth through acquisitions has sometimes been complicated.

Salesforce is helping it reach more customers. [AGI underwent an extensive data governance process](#),²⁹ using automation solutions to cleanse and deduplicate its data before importing it to Sales Cloud. That gave them comprehensive and accurate customer lists for the first time, which helps it sell more collaboratively across teams. With customers responsible for large commercial facilities worth tens of millions of dollars, AGI has simplified the bid review process by creating a fully automated solution in Sales Cloud. And using Salesforce's low-code platform, AGI is gradually extending automation to more departments.

DX AT WORK

SAP

DX at Work: Smoothing Distribution for Global Names

With sales of more than one billion products a day, Nestlé S.A. is one of the world's largest food and beverage companies and aims to source 20 percent of its key ingredients from farmers adopting regenerative agriculture practices by 2025, and 50 percent by 2030.

Nestlé is enhancing the customer experience for its business customers by streamlining the ordering, tracking, and invoicing processes. To do this, the company [implemented a global platform based on SAP Commerce Cloud](#).³⁰ This platform eliminates the need for telephone contact by providing real-time insights into orders, invoices, and delivery information.

By offering a digital self-service portal, Nestlé improves the ordering and payment process, making it easier, quicker, and more efficient for retailers, wholesalers, supermarkets, and distributors.

SECTION 3

Managing Future Needs

AI can do a great deal to streamline agricultural practices that have evolved over millennia, but it can also help humanity make a more fundamental shift. The [planet's resources are stretched to breaking point](#),³¹ according to the Stockholm Resilience Centre, meaning there is a need to completely rethink the way we produce and consume food, especially proteins. At the same time, Gallup's latest Consumption Habits poll finds [4 percent of Americans](#) say they are vegetarian and 1 percent vegan.³²

At the same time, one in four Americans are trying to [eat less meat](#). The changes in food systems required to keep pace with these trends require digital innovation. Consumers are increasingly open-minded, so governments need to think about regulatory structures that enable innovation in farming to flourish while ensuring food safety and security.

There is willingness to invest in this space: PeakBridge Ventures was founded in 2000 and manages multiple foodtech funds, including several with a focus on using data and AI. Investments have included Imagindairy, which offers "real milk, no cows," Orbisk, a Dutch company working on food waste in hospitality and Neolithics, an agri-tech company that aims to reduce food waste with optical sensing AI-software.

AI helps make discoveries that humans can't about these new frontiers of farming. For example, an AI engine watching crickets on a farm in Vietnam discovered that crickets will stop mating when they sense [a typhoon approaching from 60 miles away](#).³³ From using machine learning to [optimize precision fermentation](#),³⁴ to [creating lab-grown meats](#),³⁵ AI has an indispensable role to play in the farms of tomorrow.

DX AT
WORK

SIEMENS

Ingenuity for Life

DX at Work: The Only Way Is Up in Dubai's Vertical Orchard

Located near Al Maktoum International Airport at Dubai World Central, Bustanica is a 330,000 sq ft (7.5 acre) facility that can grow more than one million kg (1,102 tons) of exceptional quality leafy greens annually, while using 95 percent less water than conventional agriculture. Lettuce, spinach, parsley, and kale are grown without pesticides or herbicides, and enjoyed by customers across the UAE and passengers on Emirates and other airlines.

This beacon of innovation would [not exist without several Siemens solutions](#),³⁶ including the Sinamics system that circulates and recovers water, saving 250 million liters (about 66 million gallons) of water a year, compared to traditional outdoor farming. Building management system Desigo CC controls and monitors air-conditioning and ventilation, while Simatic automation and control systems deliver optimal growing conditions by controlling the lights and CO₂ levels required by the plants. This smart infrastructure enables the future use of AI, so Bustanica can become a model for other vertical farms around the world.

Conclusion

Agriculture's digital transformation is well underway: farmers are used to optical sorting of produce, auto-steering guidance systems for row crops, and weather prediction systems that transform their work. According to some estimates, [87 percent of businesses in the US agricultural industry were using AI in some shape or form](#)³⁷ as of late 2021.

But a new season is coming, where farming goes beyond the field, guesswork is further removed from the fields, and consumers make data-informed decisions about everything from calorie counts to sustainability. The government is providing financial incentives to speed up development and deployment of AI across the country. To truly harvest the benefits of AI, farmers worldwide should embrace the new wave of tools at their fingertips.

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