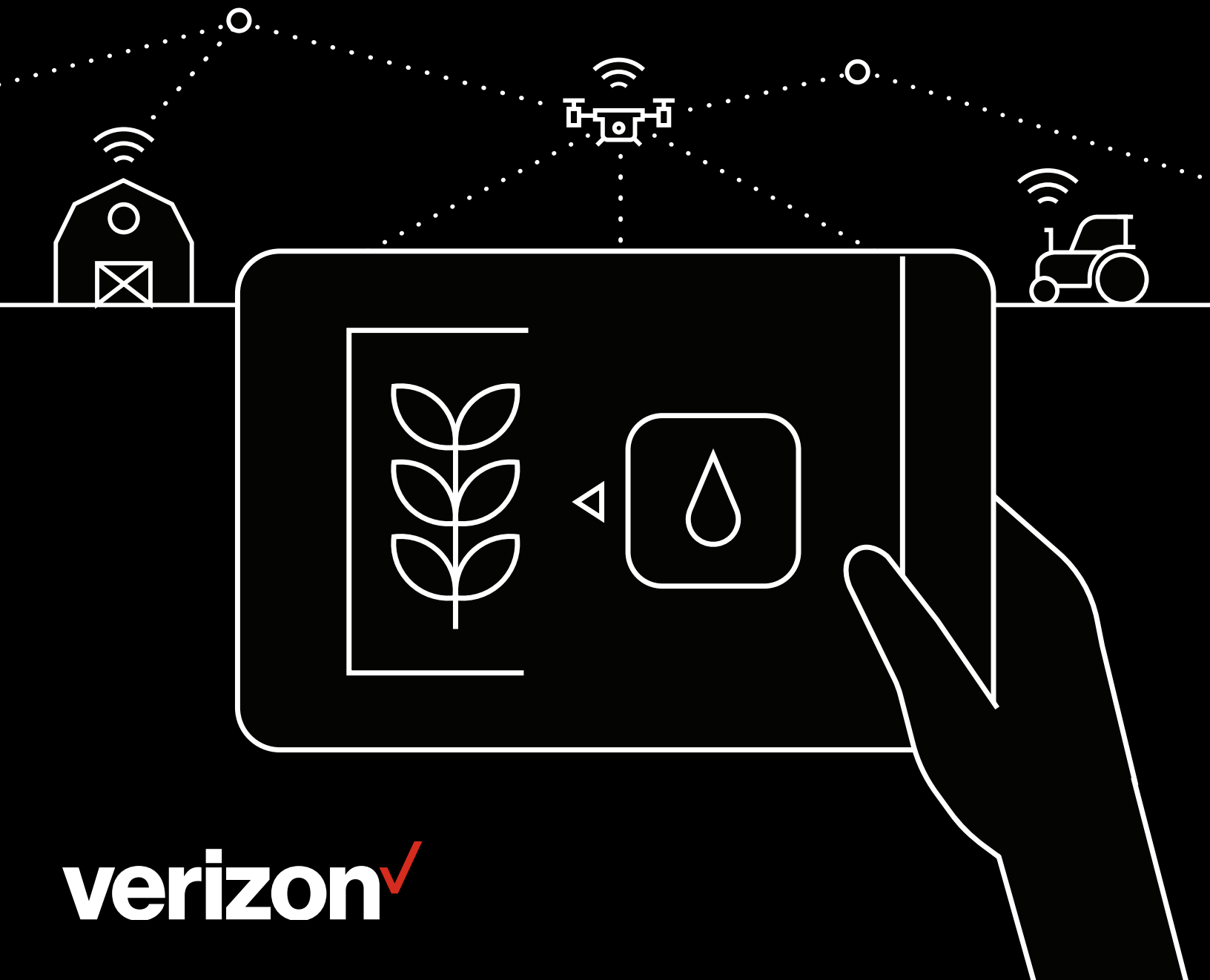
White paper

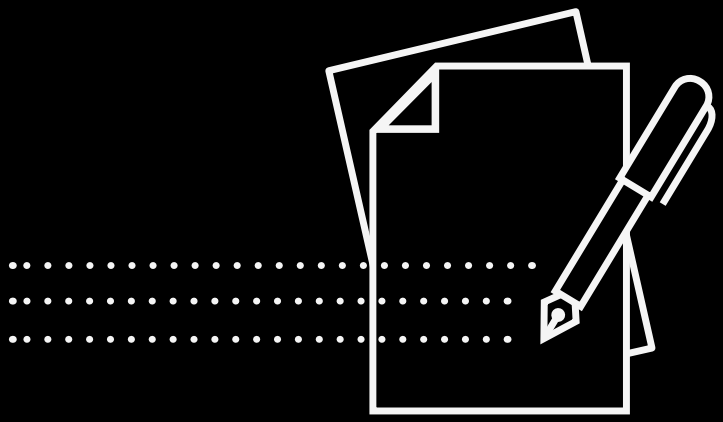
How smart agricultural technology is driving sustainable farming



verizon

Table of contents

Executive summary



Technological innovation coupled with farmers' intimate knowledge of their craft is paving the way for farming 4.0 that will be more sustainable and efficient than ever before. This new era of "smart" and sustainable farming is transforming food production by harnessing a range of emerging and established information, communications and processing technologies, from multi-access edge computing (MEC) and fifth-generation networking (5G) to advanced sensors and artificial intelligence (AI).

This paper examines how new and emerging farming technologies can enhance and, where needed, transform traditional practices to meet the challenges that lie ahead. Read on for a look at how smart farming technology enables:

- New efficiencies.
- Greater yields with less waste.
- Decreased reliance on manual labor

The agricultural industry has always been an early adopter of technology. From plows to tractors and combines, technological advances and innovations have helped farmers yield crops faster and manage livestock better for over a century.

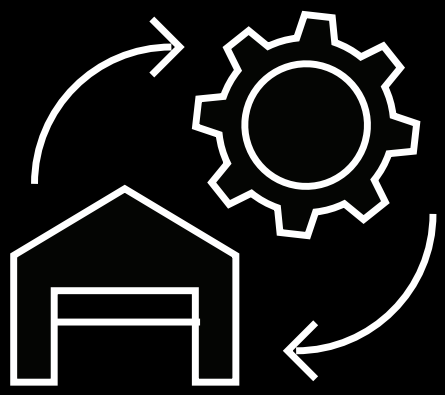
The advent of smart agriculture and sustainable farming technology, however, is ushering in a new, entirely transformative era of sustainable food production. The smart farm of the future will harvest more while using fewer resources and producing less waste, creating an exponentially more efficient and sustainable farming sector.

This shift is not just about what is technologically possible, however, but what is required; farming expenditures account for more than $350 billion in the U.S., and demand is rising,[1] while natural resources are becoming more scarce.[2] In 2013, the United Nations (UN) estimated that the world would need to produce around 70% more food by 2050[3] to feed the 9.7 billion people it expects to be on the planet by then.[4] Yet this must be achieved in line with international climate change mitigation targets and the UN's Sustainable Development Goals. Greenhouse gas emissions from agriculture are currently a major contributor to global warming.[5]

The development and adoption of "agritech," an umbrella term for smart farming technologies, is centered on meeting these challenges, as well as overcoming growing issues around water and labor scarcity and controlling pests and diseases.

"Savvy farmers are already utilizing smart farming technologies. From machines connected via the Internet of Things (IoT) to crop-watering drones and hydroponic warehouses enhanced by AI, it may be nascent, but the farm of the future has already arrived."

Increasing efficiency



A key driver of future farm technology is the goal of enabling agriculturists to achieve exponential efficiency gains across their operations that not only reduce costs and increase yields but also make new things possible. This may include shifting production closer to consumers, managing assets more efficiently, automating repetitive tasks and using big data to find solutions and diagnose problems faster.

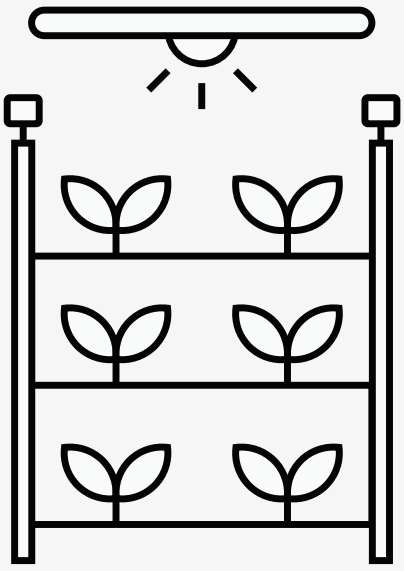
Vertical farming: fewer resources, higher yield

A burgeoning example is the development of vertical farming. Typically located in warehouses close to city centers, the environment in these farms is closely controlled and monitored by strategically placed sensors that collect data points on crops. The information is then processed by AI and machine learning algorithms to cultivate optimal growing conditions.

Due to their closely monitored and controlled environment, vertical farms typically use fewer resources. For example, US vertical farm company Plenty says its technology can yield as much as 350 times more produce in a given area as conventional farms using only 1% of the water.[6] This is notable considering the World Bank reports that farming accounts for 70% of the world's water withdrawal via irrigation.[7] As climate change disruption increases, so will the cost of and competition for water.

To use less of this precious natural resource but still yield first-class crops, the company deploys enhanced sensor systems that monitor the health of each individual plant, ensuring each receives the exact amount of water it needs, mitigating waste. It also uses LED lights in the ideal spectrums and amounts to create photosynthesis. The photosynthetic wavelengths are synced with the crop's growth to minimize energy usage and optimize yields.

Other companies developing vertical farms, such as Iron Ox, take a "robotics-first" approach, using robots with cloud-based "brains" to automatically manage the crop-growing system.[8] The US imports around 32% to 55% of the fresh fruits and vegetables its population consumes,[9] and vertical farming proponents say it can help reduce this reliance on imports, as well as cut carbon emissions by shrinking transit times. Additionally, because the crops grow upwards, often on horizontally stacked shelves, they require much less space per crop compared to conventional farming operations.

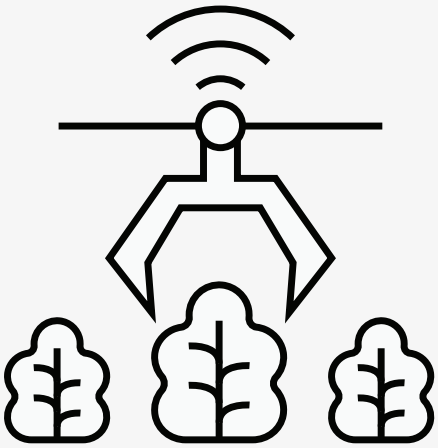


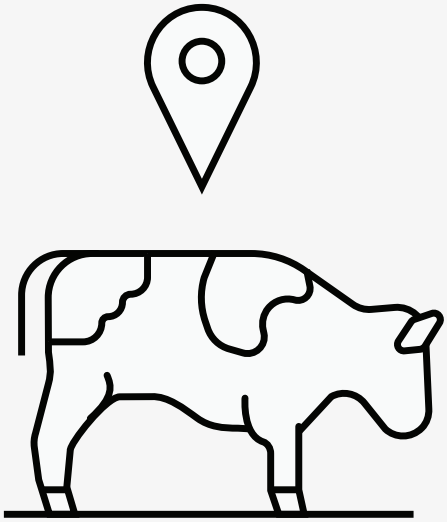
Increasing efficiency

AI in agriculture for real-time insights

The use of AI in agriculture is set to rise. A report by Million Insights estimates that the global artificial intelligence in agriculture market will reach $2.9 billion by 2025, with a projected compound annual growth rate of 25.4%.[10]

This extends to IoT technologies and robotics. A "connected farm" with sensors and dedicated 4G or 5G networking can deploy wireless (and often solar-powered) robots and devices to improve the efficiency of crop management. The higher speed and lower latency of 5G enables near real-time data transfer, helping to ensure the safe use of robotics in an agricultural setting. Two examples on the market today are Ecorobotix[11] and Naïo,[12] both autonomous weeding robots that use cameras, AI and machine learning to identify and treat weeds in the field. Where possible, shifting jobs like weeding to an autonomous smart robot can save time and reduce laborious work.



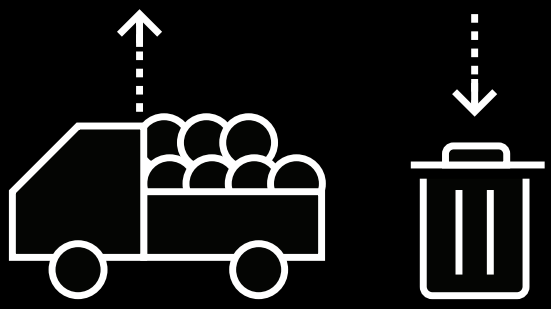


Monitoring assets with GPS tracking

Similarly, new devices that use GPS technology to track assets like cattle across expansive farmland are helping farmers more efficiently monitor and reduce the loss of livestock. These devices, in part, delegate health and location monitoring of cattle to agritech devices reducing the burden on farmers.

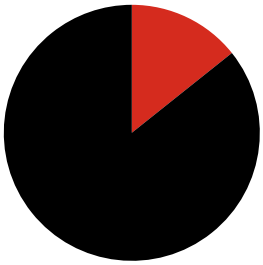
For example, ear tags, such as those developed by Moocall, geolocate a cow as well as monitor eating, drinking and other behavior to assess their well-being.[13] This technology can save farmers considerable money by flagging health issues early. In the UK, it is estimated that livestock farmers lose £270 million each year due to parasitic worm infections alone.[14] In addition, the tech can check when a female cow is in heat and a pregnant one is ready to give birth. GPS tracking devices can also be used for technology fleet management so farmers can identify where vehicles are at all times.

Increasing yield and reducing waste



While enough food is produced to feed the population of the entire world,[15] 14% of all food produced never makes it to the consumer, according to the UN Food and Agriculture Organization.[16] This loss, which occurs throughout the production and food supply chain, from harvest up to the retail level, will need to be curbed if the agriculture sector is to successfully feed growing populations while also reducing emissions.

Key causes of on-farm losses include inadequate harvesting time, climatic conditions, harvesting practices and challenges in marketing produce.



14%

Of all food produced never makes it to the consumer.

> **"5G networking, handheld devices and edge computing technology can make the technology more user-friendly, accessible and affordable to farmers."**

Precision agriculture for crop resilience

However, using smart farming technology, farmers of the future should significantly reduce waste; harnessing the power of big data and smart monitoring can enable agronomists to produce better, more resilient crops. For example, precision agriculture, which is a farming management concept based on observing, measuring and responding to site-specific crop management, supports more sustainable farming by providing customized, rather than uniform, solutions for better outcomes and reduced use of pesticides, water and waste.

Precision farming requires agronomists to have detailed real-time data on the condition of each crop on the ground and the ability to quickly diagnose problems. Considering the large crop fields farmers typically manage, this can only be achieved with the help of technology such as satellite imagery, IoT sensors and AI. Once the data is collected, it can rapidly be analyzed by farm management software that, coupled with detailed information on weather forecasts and patterns, can provide specialized insights and recommendations on crop management. 5G networking, handheld devices and edge computing technology can make the technology more user-friendly, accessible and affordable to farmers.

Increasing yield and reducing waste

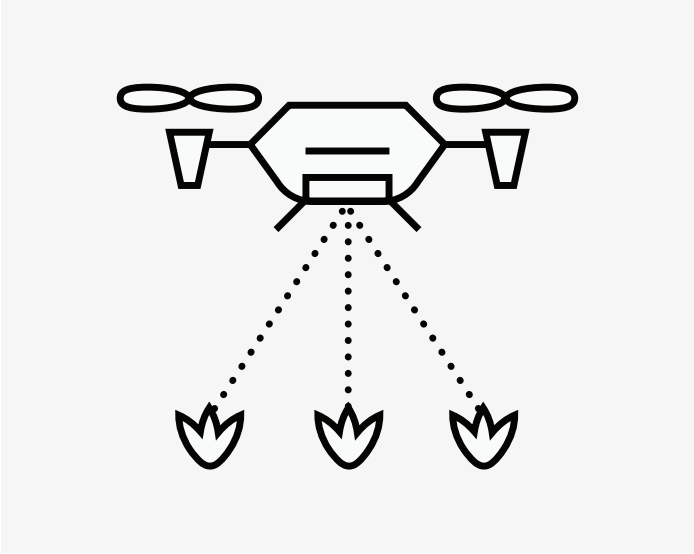
Faster inspection with drones and robots

Cellular-connected drones equipped with cameras can also be used to quickly inspect a large expanse of land to closely monitor crop fields and cattle. The footage can later be reviewed using cloud-based video analytics and AI to identify anomalies. Approximately 20% to 40% of the produce from cultivated crops die each year globally from diseases and pests;[17] however, specially equipped drones can help spot issues quickly as they arise and before they manifest.

Technology examples in this field include Israeli-startup Taranis,[18] which images whole fields with light sport aircraft and drones. Using image-processing algorithms to stitch together the pictures, it produces a unified field photograph down to leaf level to identify zones in need of attention. Combining this with granular field-level weather forecasts, it recommends the most effective time to apply treatments or highlights the best planting window. This helps reduce the waste of costly materials due to unforeseen weather conditions.

EarthSense has produced a ground robot that generates a detailed portrait of crops, including height, condition and leaf-area index, in the field.[19] Called the TerraSentia, it uses a mix of sensors – such as visual cameras, light detection and ranging (LIDAR) tools and GPS devices – to autonomously collect data on plant health, physiology and stress response. Its cloud-based platform enables agronomists to teach the robot to automatically measure a range of key traits.

Such detailed information, which farmers in the past would have collected by hand, helps agronomist select the best plants to use to create hybrids or for producing more resilient and sustainable crops in the future. The data can also be fed into algorithms to understand how future crops may behave and be managed more sustainably.



5G geolocation services for waste reduction

To further reduce the chance of spoiled crops, 5G-powered geolocation services and sensors can help track insects, soil conditions and other metrics, relaying data back from the field. Delivering this information to a farmer in real time – and using software to monitor it and send an alert when there is a problem – is invaluable given that small changes in on-the-ground conditions, such as moisture and temperature, can have a big impact on crop yields.

Importantly, this technology can also reduce harvesting costs in the long term, so acres of ripe crops don't go unharvested because of the expense for pickers and shipping. A sample study of 123 fields of hand-harvested crops in California by Santa Clara University found that one-third of edible produce is left unharvested in the fields.[20]

Decreasing manual labor

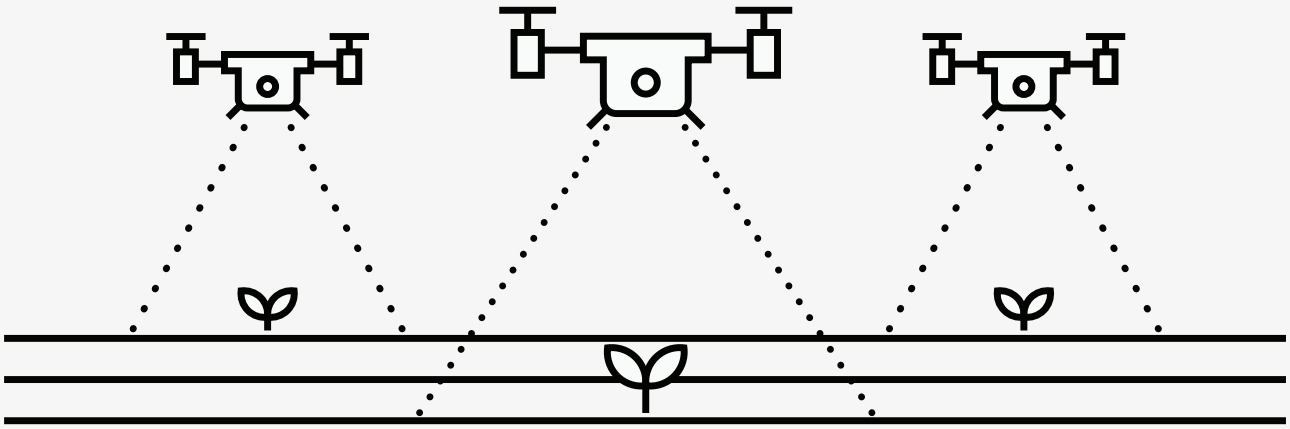
Labor scarcity is a major challenge facing the agriculture and farming sector, particularly in developed countries. The age of the average farmer in the US, for example, is 57 years old,[21] and young people are not taking up work in the industry at the rate needed. Furthermore, disruption caused by the COVID-19 pandemic, which resulted in travel restrictions greatly reducing the movement and availability of workers, has given countries that rely heavily on seasonal crop pickers pause for thought.

Smart farming technology, paired with reliable cellular connectivity, 5G networks and IoT technology can fill the human labor void and attract a new generation of tech-savvy farmers with it. The majority of agritech is designed to make farmers' work easier and more informed. Some tasks, such as the repetitive and visual but also increasingly more complex ones, can even be delegated completely to robotic technology, the cost of which is falling rapidly.

Delegating work to drones

When it comes to reducing the need for human labor, some applications have more impact than others. Drones, for example, are proving ideal. Drone technology, which is increasingly becoming more sophisticated, can cover large swathes of land in a fraction of the time a human could do it.[22] Using the DJI Agras MG-1, for example, a single farmer can map out a field and feed or spray pesticides across as much as 80 acres of crops a day, much faster than doing it manually.[23] This time can be reduced even further by using a swarm of drones programmed to work together, a capability drone software developers are increasingly focusing on.

In a similar vein, prototype drones are being tested to replace manual labor for seeding and planting by using pressurized air to fire capsules containing seed pods with fertilizer and nutrients directly into the ground.[24]



Decreasing manual labor

Robots support the workforce

Eventually, agriculture is expected to follow in the footsteps of other industries, such as mining, by adopting completely autonomous machines to reduce reliance on human labor. Like the mining sector, which commonly uses autonomous hauling trucks to transport ore, many aspects of farm work are labor-intensive, repetitive and hands-on. These tasks, which are also known as the "dull and dirty" jobs, are the ones that can most easily be delegated to robotics and automation. Specialty harvesters, tractors and combines equipped with sensors, AI and cameras and using 5G's super-fast connectivity could automatically complete tasks when conditions are ideal, freeing farmers to do other things. As robots don't get tired, they can work for 24 hours a day.

A ground-breaking area of innovation in this space is the development of autonomous robot crop pickers that can handpick ripe fruit and vegetables. Harvesting, which accounts for 20% of all agricultural work,[25] could be left entirely to robots, relieving pressure from labor shortages and reducing the number of harvest-ready fields that are abandoned because there is not enough affordable labor to pick the crops.

Fieldwork Robotics is trialing a robot it has developed that can pick more than 25,000 raspberries a day, outperforming human workers who can pick roughly 15,000 in an eight-hour shift.[26] With guidance from sensors and 3D cameras, using machine learning, its gripper identifies and picks ripe fruit.

Panasonic has also developed a tomato-picking robot.[25] Suspended from a rail, the robot is equipped with a camera that has an image recognition function that helps it to identify tomatoes and whether they are ready to be harvested or not. While the robot collects tomatoes slightly slower than the average human picker, it can work for 10 consecutive hours or more, meaning it is more efficient overall.

"Harvesting, which accounts for 20% of all agricultural work, could be left entirely to robots"

Future emerging innovations

Other labor-saving innovations in the pipeline include IoT-enabled subsurface drip irrigators (SDI), technology routinely used to allow farmers to control water feeds to crops. Teaming SDIs with IoT-enabled sensors allows farmers to continuously monitor moisture levels and plant health. They can operate autonomously using machine learning.

With 5G as the standard, the farm of the future will be able to utilize its fast speeds and low latency for a plethora of connected devices to make plowing, sowing, feeding, health-monitoring and harvesting happen completely autonomously. This will exponentially improve efficiency, ensure crops are harvested as soon as they are ready, improve shelf-life, reduce waste and prevent labor shortages from being prohibitive.

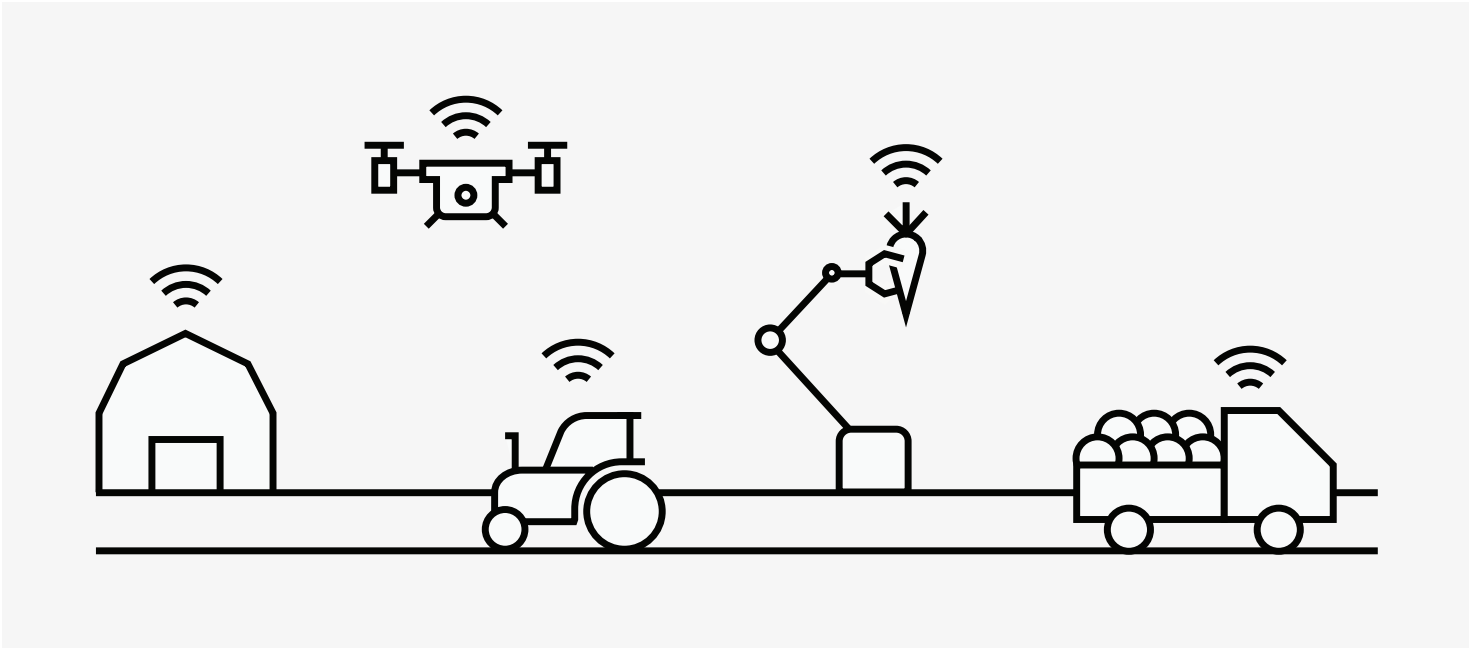
The farm of the future

Farming 4.0 is a must if the industry is to meet the challenges of feeding an increasing population amid a rapidly changing climate. Fortunately, the connected farm of the future will know no bounds. With this level of connectivity, farmers can harness almost any new technology innovation to revolutionize their industry, creating entirely new practices and enhancing others. Managing current and new challenges should be easier with 5G, big data and analytics at a farmer's disposal. Similarly, decision-making should be quicker and more informed. Overall, smart farming can deliver fewer delays, less labor-intensive work, increased yields at lower costs and a more sustainable industry.

Data from AgFunder, an online venture capital platform, suggests the industry is already taking heed of the advantages of smart farming. It found the amount of money invested worldwide in agricultural and food technology reached $19.8 billion in 2019, with a 250% growth rate over the past five years.[27]

The rollout of 5G, coupled with edge computing technology, can take the agricultural industry to the next level of innovation. Verizon 5G, with its super-fast data transmission, ultra-reliable low latency and massive network capacity, which can support millions of devices per square meter, will enable a farm to benefit from being connected, creating new opportunities and applications.

The expertise and wisdom of farmers will always be paramount. But with the right network partner, agritech and smart farming technologies can enhance this knowledge to help farmers more efficiently manage their time and resources so they can focus on what really matters.



Learn how

Verizon 5G edge technology can help bring farming into the future.

verizon

1. “U.S. Farm Production Expenditures, 2019,” USDA National Agricultural Statistics Service (July 2020).
2. “Climate change and resource scarcity,” PricewaterhouseCoopers UK.
3. “World must sustainably produce 70 per cent more food by mid-century – UN report,” UN News (December 3, 2013).
4. “Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion around 2100,” UN Department of Economic and Social Affairs (June 17, 2019).
5. “Food production is responsible for one-quarter of the world’s greenhouse gas emissions,” Hannah Ritchie, Our World in Data (November 6, 2019).
6. “About Us,” Plenty
7. “Chart: Globally, 70% of Freshwater is Used for Agriculture,” Tariq Khokhar, World Bank Blog (March 22, 2017).
8. Iron Ox.
9. “FDA Strategy for the Safety of Imported Food,” US FDA (February 2019).
10. “Artificial Intelligence in Agriculture Market Analysis Report By Component, By Technology, By Application, By Region And Segment Forecasts From 2019 To 2025,” Million Insights (August 2020).
11. “AVO in Agronomic Test at KWS,” Ecorobotix.
12. Naïo.
13. Moocall.
14. “New study reveals the true cost of worms to UK cattle farmers,” The Cattle Site (August 18, 2020).
15. “The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Healthy Diets,” Food and Agriculture Organization of the United Nations (2020).
16. “The State of Food and Agriculture 2019,” Food and Agriculture Organization of the United Nations (2019).
17. “New standards to curb the global spread of plant pests and diseases,” Food and Agriculture Organization of the United Nations (April 3, 2019).
18. “Technologies,” Taranis.
19. EarthSense.
20. “On-farm food loss in northern and central California: Results of field survey measurements,” Gregory A. Baker, Leslie C. Gray, Michael J. Harwood, Travis J. Osland, Jean Baptiste C. Tooley, Resources, Conservation and Recycling (October 2019).
21. “2017 Census of Agriculture Highlights: Farm Producers,” USDA National Agricultural Statistics Service (April 2019).
22. “Drone technology uses and applications for commercial, industrial and military drones in 2020 and the future,” Divya Joshi, Business Insider (December 18, 2019).
23. “Agras MG-1,” DJI.
24. “This tech company is aiming to plant 500 billion trees by 2060 – using drones,” Kate Whiting, World Economic Forum (December 4, 2019).
25. “Introducing AI-equipped Tomato Harvesting Robots to Farms May Help to Create Jobs,” Panasonic Newsroom Global (May 23, 2018).
26. “Robocrop: world’s first raspberry-picking robot set to work,” Julia Kollewe and Rob Davies, The Guardian (May 26, 2019).
27. “AgriFood Tech: 2019 in Review,” AgFunder (2019).