AEM
Association of Equipment Manufacturers

An analysis of **13 trends** that could reshape the way food is produced

Introduction

Consumers have a growing desire to know more about where their food comes from. At the same time, supply chain vulnerabilities, environmental challenges, demographic shifts and advances in technology are prompting regulators, investors and growers to view the processes of food production and distribution through a different, more critical lens.

America's farmers have already cemented their legacy as the most essential of workers. Their willingness to assume enormous levels of risk and work tirelessly to help secure a critical supply chain is unparalleled. Plus, they do it all while managing millions of acres of land and preserving vital natural resources.

Going forward, farmers and the shrinking skilled workforce will be asked to do even more. Meeting tomorrow's challenges will require a new way of thinking and, in some instances, a new way of doing business. Innovation will be the key to success in meeting the food supply chain demands.

The Association of Equipment Manufacturers (AEM) Futures Council spent countless hours discussing how the agriculture industry could be reshaped over the next 10 years. Following is a look at 13 trends that will help define the future of food production.

1 Produce more with less environmental impact

American farmers have always been responsible stewards of the land. Environmental expectations will continue to change, raising the bar even higher. Farmers will be expected to fulfill higher production needs while reducing their environmental impact — a story they are familiar with from history. Farmers will respond enthusiastically, helping to usher in a new and exciting era of agriculture over the next 10 years.

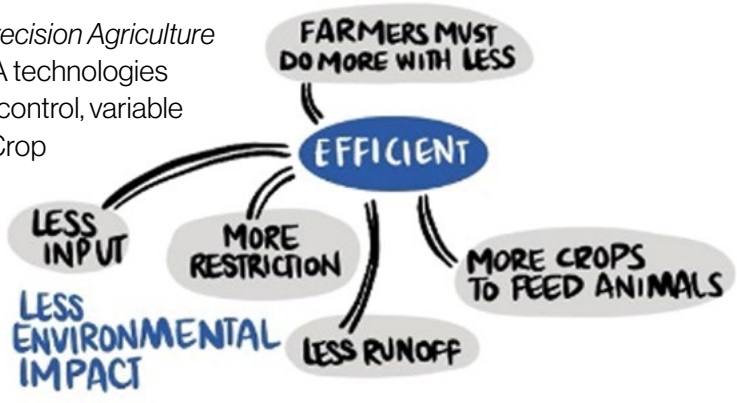
It is simply a matter of demand. As highlighted in the American Farm Bureau Foundation for Agriculture's (AFBFA) **2021 Food and Farm Facts Book**, one U.S. farm feeds 166 people annually in the U.S. and abroad. The global population is expected to increase by 2.2 billion by 2050, which means farmers will have to grow roughly 70% more food than what is now produced. As always, American farmers will rise to the occasion, accepting this monumental challenge as their next great opportunity.

Maximizing the potential of every acre farmed will be essential. Progress has been made over the past several decades. For instance, the AFBFA reports that careful stewardship by U.S. food producers has spurred a 34% decline in erosion of cropland by wind and water since 1982. However, more will need to be done to meet the needs of the future.

GLOBAL POPULATION IS EXPECTED TO INCREASE BY 2.2 BILLION BY 2050

Precision agriculture (PA) is one approach that will continue to help crop farmers meet the growing expectation of producing more with less impact. An **article** published by the USDA says PA is a general term used to describe farming tools that are based on observing, measuring and responding to within-field variability. It is a specific application of artificial intelligence. PA enables growers to make resource management decisions based on specific field irregularities, hence the term "precision."

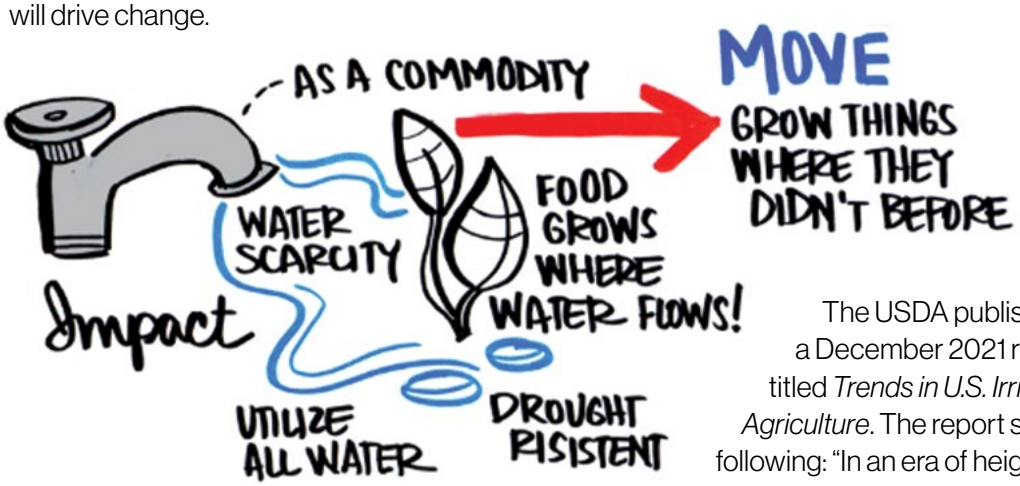
AEM's study *Environmental Benefits of Precision Agriculture* examines the impact of leveraging key PA technologies such as auto guidance, machine section control, variable rate technology and machine analytics. Crop producers leveraging PA technologies saw a 4% increase in crop production, 7% increase in fertilizer placement efficiency, 9% reduction in herbicide and pesticide use and 6% reduction in fossil fuel use.



The evolution of technology and its adoption will be key to meeting the production demands. Another game-changing PA technology is precision irrigation, which intersects with another critical trend helping to shape the future of food production: water use.

2 Optimization of water use

Concerns over depleting water resources will compel growers to embrace the latest technologies and farming practices in an effort to improve soil management and to optimize water use. Considering food security is contingent upon water security, this trend will drive change.



The USDA published a December 2021 report titled *Trends in U.S. Irrigated Agriculture*. The report states the following: "In an era of heightened water scarcity motivated by successive severe drought events affecting major U.S. agricultural regions, policy emphasis has turned to building drought resiliency within agricultural systems. Additionally, concerns about surface water supply shortfalls and groundwater depletion across major agricultural regions has policymakers focused on vulnerabilities of the irrigation sector. Improved irrigation water management practices (e.g., soil moisture sensors, weather tracking, irrigation scheduling tools, flow meters, plant condition monitoring technology, etc.) are essential in achieving maximum water-use efficiency."

Looking to the future, as both population and food consumption increase, water-use pressures certainly will not relent. Furthermore, if Americans make their anticipated shift to a diet with more nuts, fruits, vegetables and dairy, the USDA predicts that freshwater withdrawals will increase by roughly 16% (May 2020 report, *Resource Requirements for Food Demand in the United States*).

WATER SUPPLIES WILL FALL
40% SHORT
OF MEETING GLOBAL NEEDS
BY 2030

Considering the fact that demand for food in general is increasing, an **article** from McKinsey & Company suggests that water supplies will fall 40% short of meeting global needs by 2030. Farmers have taken extraordinary steps over the years to conserve water while still ensuring a stable food supply. By embracing a new, technologically driven way of producing food, even more progress can be made in the future.

The USDA says growers can increase **drought resilience** through many actions, including investments in irrigation efficiency and tactics that enhance soil moisture-holding capacity. A provider of soil sensors says water-holding capacity is actually the largest driver of yield

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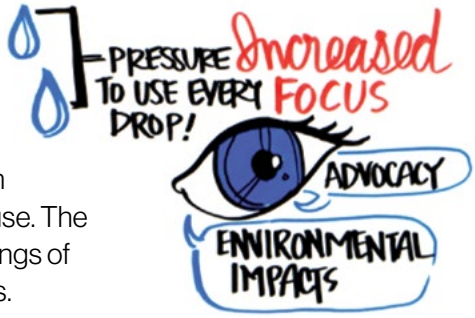
Optimization of water use *continued*

potential. Additionally, the USDA says a variety of management practices that increase soil organic matter while reducing soil moisture loss—such as no-till or reduced tillage, the use of cover crops and conservation crop rotations—can help farms adapt to drought risk. PA will also play a crucial role. The AEM study on PA shows that growers utilizing precision irrigation technologies realized a 4% reduction in water use.

Another strategy to optimize water use relates to the types of water being utilized for agriculture. The USDA report *Trends in U.S. Irrigated Agriculture* says non-traditional water sources have included recycled, reclaimed and desalinated. Reclaimed (treated wastewater) in particular saw an increase in the amount used per acre from 2013-2018. Still, acres using reclaimed or recycled water account for less than 2% of total irrigated acreage. Expanding their use, however, is a promising development.



Closed-loop irrigation systems present another opportunity for the agriculture industry. A study presented in the *Journal of Cleaner Production* compared a closed-loop water system to a linear system with no nutrient or water recovery on a rooftop greenhouse. The study found that the closed-loop system had a 40% savings of irrigation water daily and retained 35-54% more nutrients.

Over the next 10 years, growers will also be looking to new seed varieties that help them produce more while optimizing water use. For instance, a major life science company has created a rice seed hybrid. It is more adaptable to different climates and optimizes water and nitrogen efficiency by having a more developed root system.

Growers will become increasingly willing to challenge conventional norms

Growers will become increasingly willing to challenge conventional norms, freeing them to make more strategic decisions on which crops should be planted where based on water availability. In drought-stricken areas, for instance, **sorghum** presents opportunity. Sorghum tolerates drought better than most crops due to its finely branched root system and small leaf area which limits transpiration. Furthermore, sorghum can essentially turn dormant during exceptionally dry periods, only to resume growth once conditions become favorable again. For this reason, many countries dealing with regular droughts are increasing the use of sorghum in place of corn as a feed for livestock.

With water a vital resource in the production of crops and the raising of livestock, demand will grow as food demands increase. Over the next 10 years, farmers will continue to advance their legacy of water conservation by embracing the tools, technologies and cultural practices that enable them to efficiently deliver the right amounts of water at precisely the right times.

3 Increased global demand for protein

As the global population grows and larger segments of society advance up the economic ladder, demand for protein will increase significantly. Both animal-based proteins and plant-based alternatives are forecasted to grow, giving American farmers several ways to continue feeding the world.

The Food and Agriculture Organization of the United Nations (FAO) says per capita food consumption (kcal per day) has been increasing since the 1960s, largely driven by a shift from roots and tubers to livestock products. Additionally, as nations develop, more people begin consuming more proteins as their incomes rise and they move to urbanized areas.

Demand for animal protein is expected to double by 2050

Animal protein will continue to benefit from its long history of consumer acceptance. The FAO projects that **annual meat production** is on a trajectory to achieve a 72% increase in 2030 as compared to 1999. Looking a bit further onto the horizon, **demand for animal protein** is expected to double by 2050.

Dairy consumption in the U.S. is also remaining strong, although some data suggests that non-dairy alternatives (almond, soy, coconut and oat) are beginning

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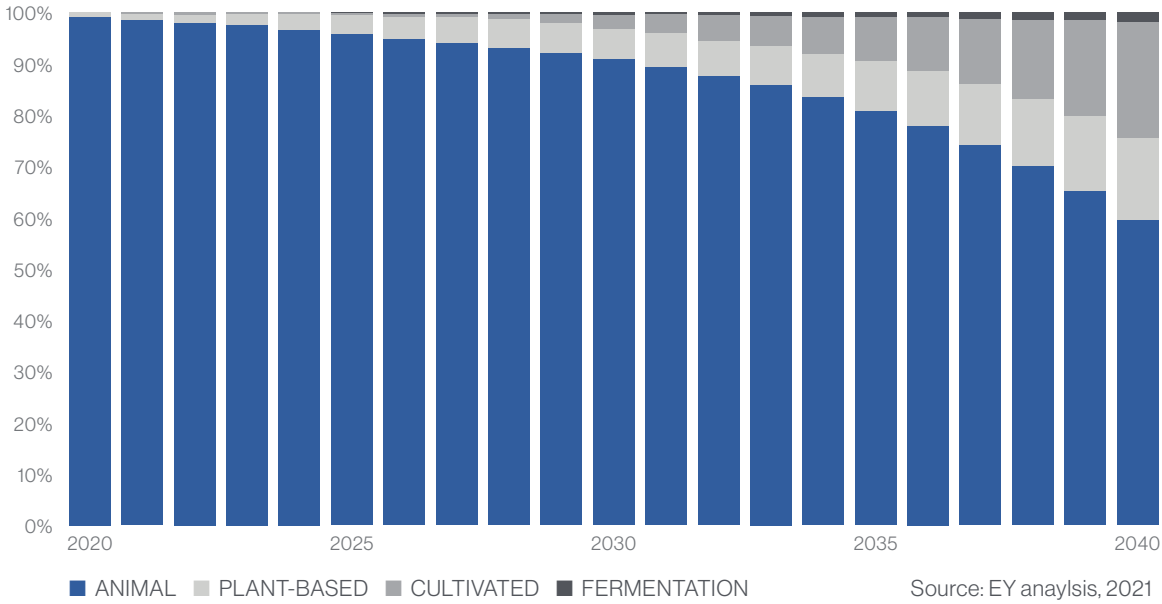
Meat consumption by source 2020-2040 (% of total; excludes fish)



Source: EY anaylsis, 2021

Increased global demand for protein *continued*

to claim a share of the market. **Mintel** is a market intelligence agency that tracks consumer spending. Their research revealed that non-dairy milk sales grew 61% from 2012-2017. Hemp milk presents another opportunity for U.S. growers. **Verified Market Research** predicts that hemp milk will grow at a compound annual growth rate of 15.4% from 2021-2028. Hemp is a versatile crop that grows quickly and often produces excellent yields. Nonetheless, dairy still maintains its dominant share of the milk market. **AgDaily** reports that plant-based alternatives have been showing healthy year-to-year growth, but still represent just 15% of the fluid milk market.

Plant-based meat alternatives are also on the rise. **NielsenIQ** reports that sales increased 60% from 2019-2021, largely because availability, price point and taste have all improved. Furthermore, **Grand View Research** predicts that the global market will expand at a compound annual growth rate of 19.3% from 2022-2030. Still, plant-based meats have just a small share of the overall meat market. In fact, data from the **Plant Based Foods Association** suggests that roughly 2.7% of retail packaged meat sales in 2020 were plant-based meats.

> **Plant-based meat alternatives are also on the rise**

Putting all this together, it is clear that over the next 10 years demand for all types of proteins will expand. In their never-ending quest to put good, nutritious food on people's tables, American farmers will adapt their production operations accordingly to ensure that the global market has the reliable, diversified food supply required to meet both current and future protein consumption needs.

Per capita consumption of livestock products

REGION	MEAT (KG PER YEAR) 1964-1966	1997-1999	2030	MILK (KG PER YEAR) 1964-1966	1997-1999	2030
World	24.2	36.4	45.3	73.9	78.1	89.5
Developing countries	10.2	25.5	36.7	28.0	44.6	65.8
Near East and North Africa	11.9	21.2	35.0	68.6	72.3	89.9
Sub-Saharan Africa*	9.9	9.4	13.4	28.5	29.1	33.8
Latin America and the Caribbean	31.7	53.8	76.6	80.1	110.2	139.8
East Asia	8.7	37.7	58.5	3.6	10.0	17.8
South Asia	3.9	5.3	11.7	37.0	67.5	106.9
Industrialized countries	61.5	88.2	100.1	185.5	212.2	221.0
Transition countries	42.5	46.2	60.7	156.6	159.1	178.7

* Excludes South Africa. Source: Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases

4 Shorter food supply chain

Demand will grow for locally sourced food and overall shorter food supply chains. Farmers will utilize a variety of direct-to-consumer marketing tactics to capitalize on this opportunity. Additionally, restaurants, schools, hospitals and other institutions will increasingly look to local food providers in an effort to ensure a reliable supply of high-quality food, while also benefiting the local economy.

Schools, for example, are beginning to revert back to the **nutritional standards** set for the National School Lunch Program during the Obama Administration. Those standards require more whole grains, fruits and vegetables while reducing sodium. Now the USDA is planning an entire reboot of nutritional standards for school meals in 2024/2025 which will include sugar limits. With more emphasis on fresh foods, local farmers are in an excellent position to help fill local schools' food needs.

According to a **report** published by the USDA in October 2021, local food production currently represents a small share of the overall U.S. food system. But it's growing. Sales of local edible farm products in 2017 totaled $11.8 billion, or 3% of all agricultural sales. That's a 35% increase from the $8.7 billion sold just two years prior.

The COVID pandemic is thought to have further spurred interest in locally sourced food. The Michigan State University Agriculture Extension posted an **article** in November 2020 explaining how consumer food purchasing behavior has changed. The "farm to fork" movement was already on the upswing prior to COVID-19. That trend is expected to strengthen now that additional consumers have experienced "buy local" outlets such as farmers markets. More recently, supply chain disruptions and empty grocery store shelves have triggered consumers to think about where their food comes from and how vulnerable food security can be.

DEMAND FOR LOCALLY SOURCED FOOD AND OVERALL SHORTER FOOD SUPPLY CHAINS WILL GROW

Grassroots initiatives are also helping to generate interest in locally grown food. For example, the **Food Well Alliance in Atlanta** is a network of local leaders working together to help develop an equitable, local food ecosystem driven by community gardens and urban farms. Similar groups can be seen in nearly every urban setting.

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Shorter food supply chain *continued*

Vertical farming is an emerging trend that lends itself to urban agriculture and local food production. There are many examples of investment in this area. **Upward Farms**, for example, is creating what it calls the world's largest vertical farm. This 250,000 square foot facility in Pennsylvania should be fully operational in 2023, producing locally sourced microgreens and sustainably produced bass. What's really interesting is that the products Upward Farms is focusing on have traditionally had long supply chains to reach the eastern U.S. Now these popular products will be produced locally. **Walmart** is another example of financing in this area. They have made a significant investment in vertical farming by acquiring an equity stake in Plenty, a vertical farming startup.

Over the next 10 years, more consumers and institutions will look to their communities for reliable sources of food. This shift will add strain to an already shrinking skilled workforce pool. Innovation will play a pivotal role in meeting demand while using fewer resources of people, water, and other inputs. The American farmer, a cornerstone of community and economic progress for centuries, will continue to meet that need.

5 Geographic shifts in production

Crop production will continue to shift geographically as climate changes and water resources challenge conventional approaches, creating opportunity for farmers to diversify and generate stronger returns. The impact will not only be to what farmers grow, but also how it will get to market; this change will shift the entire food supply chain.

Never short of ambition and ingenuity, American farmers have already been taking matters into their own hands. For example, **farmers in southern Kansas** have added cotton to their crop rotation strategy, providing a water-efficient option in this region.

The **World Resources Institute** discusses the importance of transforming food systems to reduce risk. For example, coffee production in Costa Rica was relocated from an especially hot area of the country and replaced with citrus which can thrive in a warmer environment. Over the next 10 years, American growers will also begin examining where certain crops can be planted in an effort to optimize water use and maximize ROI.

A study from **NASA** suggests that climate change could affect global production levels of corn and wheat by as early as 2030. Increased temperatures, changes in rainfall pattern and elevated surface carbon dioxide concentrations are all having an influence. Wheat could actually see its geographic potential grow as temperatures rise. Corn, on the other hand, could be negatively impacted since large quantities are grown closer to the equator. Each scenario presents both challenges and opportunities for growers.

Research presented by **Penn State University** suggests that if warming of the Midwest U.S. remains unabated, the best conditions for growing corn could shift northward from Illinois and Iowa to Minnesota and the Dakotas. If a shift does take place, growers in Illinois and Iowa will have to shift with it. Instead of growing corn and soybeans, they may have to adapt to a warmer climate by producing two crops in the same year, or perhaps a different mix from the typical corn-soybean rotation.

This shift requires more than just a change to what a farmer plants and harvests, but knowledge sharing into new markets and supply chain infrastructure to support it.

6 Advanced food traceability helps maintain consumer trust

Consumers will expect growers to document and share everything about their production, leading to widespread adoption of the latest food traceability technologies and more data being included on food labels.

Food traceability refers to following the movement of a food product and its ingredients through all steps of the supply chain, documenting and linking production, processing and distribution. Because traceability enables faster and more precise identification of contaminated food sources, product recalls can happen more efficiently, helping to reduce waste while still providing for public safety. Additionally, traceability helps consumers gain even more confidence in the foods they are eating.

The FDA has proposed additional **traceability recordkeeping requirements** beyond what is already required. For the growers of foods designated on the FDA Food Traceability List, this generally means providing geographic coordinates detailing where the product is grown. In the future, however, the potential is there to capture additional information. Growers could provide deeper insights into how a food was produced, including pesticides and other inputs, carbon emissions from the production process, labor wages, etc. This will largely be driven by the consumer's desire for heightened visibility into the foods they are eating as well as the companies helping to produce those foods.

> **Consumers will expect growers to document and share everything about their production**

FMI, The Food Industry Association, and Label Insight presented **research** in June 2020 that suggests consumers will help drive the shift toward traceability. Data shows that 81% of shoppers believe food transparency is important or extremely important, up 12% from a couple of years prior.

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Advanced food traceability helps maintain consumer trust *continued*

To help foster widespread adoption of food traceability tools, the FDA has launched an **initiative** asking food industry stakeholders, including technology providers, to develop traceability tools that are economical, interoperable and scalable for food operations of all sizes. Several examples of **innovative food-tracing technology** are already happening. Aanika Biosciences has developed a product that uses edible microbial tags that enable farmers to watermark crops. Another startup, Trutag, is working on an invisible edible barcode to place directly onto products. SafeTraces is using FDA-approved, food-grade DNA technology to create flavorless and invisible DNA barcodes.

There are range of innovations in food traceability throughout the food supply chain under development. All are working toward creating transparency in areas such as sustainability, nutrients, producer performance and much more.

As technology continues to create new opportunities to enhance food transparency, consumer expectations will also grow. As such, farmers will embrace the latest innovations in food traceability over the next 10 years, helping to maintain the steadfast trust they have cultivated for decades.

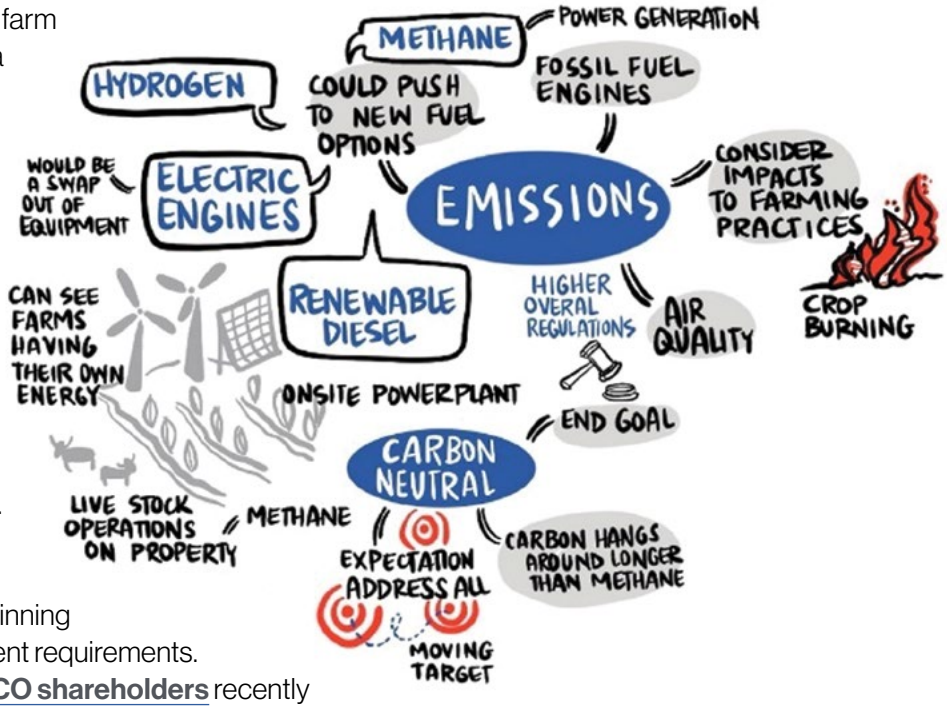
7 Farmers adjust in response to emission regulation

Ongoing emission-reduction regulations will drive alternative management practices on farms, including the utilization of cutting-edge technologies and alternative renewable power sources.

American farmers have continually made great strides to lessen their environmental impact, such as operating equipment that meets current EPA emissions regulations. Over the next 10 years, as emission-reduction goals intensify and alternative energies become more available, additional strides will be taken.

The U.S. strives to drastically reduce greenhouse gas (GHG) pollution by 2030 (50-52% reduction from 2005 levels). To that end, the EPA recently finalized its **most aggressive GHG emissions rule** for passenger vehicles and light-duty trucks for model years 2023-2026. More recently, the EPA announced plans to reduce GHG emissions and other air pollutants from **heavy-duty trucks** through a series of rulemakings over the next three years.

State governments are beginning to regulate engine-powered outdoor equipment. For instance, the California Air Resources Board (CARB) recently approved a regulation that **bans small gas engines** (up to 25 hp) on new equipment starting in 2024. It is not unthinkable that rigid regulations like this could ultimately extend to engine sizes used to power some farm machinery. There is a growing list of more than 15 other states that tend to take their cues from CARB. Sweeping changes like this can happen quickly when so much attention is placed on a given issue, as is the case with GHG emissions.



To that point, large retailers are also beginning to enact more stringent requirements. For example, **COSTCO shareholders** recently voted overwhelmingly in favor of a resolution that requires reporting and action on the company's Scope 3 emissions, which are those tied to the company's supply chain, including food producers. **Walmart** has also taken steps to enable its small and medium-sized suppliers to assist in the reduction of its Scope 3 emissions.

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Farmers adjust in response to emission regulation

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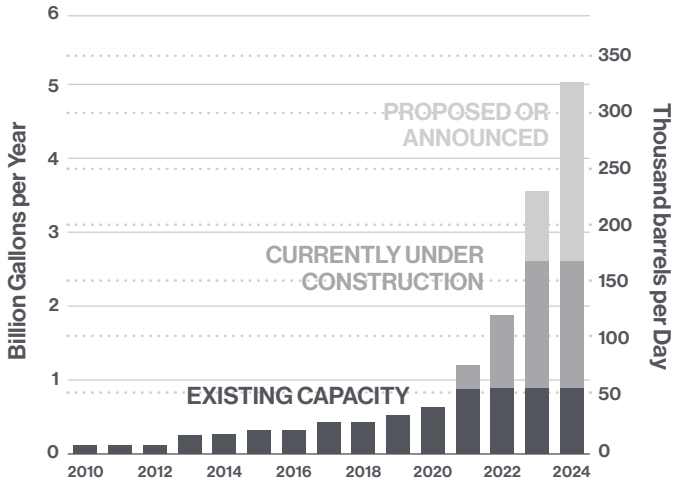
To help farmers stay ahead of the curve, the **USDA** recently invested $464 million in renewable energy infrastructure to help rural communities and ag producers improve energy efficiency and shift to renewable energy sources including solar, wind, small hydroelectric, anaerobic digesters and biomass. Farmers will also look to **alternative energies** such as biofuel, battery/solar and hydrogen fuel cells to power their machinery.

Renewable Diesel Production Expected to Grow

Existing and expected U.S. renewable diesel production capacity



Source: U.S. Energy Information Administration

Biofuels will play a growing role in the sustainability message in the next few years while also creating additional demands for crops. Corn-based ethanol has a familiar foothold in the market and should continue to grow in prominence with increased innovation in production and regulatory support. In addition to ethanol, biofuels development will expand into biodiesel. Renewable diesel fuel is chemically the same as petroleum diesel, meets ASTM specifications and can be produced from cellulosic biomass materials such as crop residues, wood/sawdust and switchgrass. Produced through thermochemical processes, renewable diesel can be blended with petroleum diesel or simply used in pure form.

"We're in the early adoption phase with renewable diesel, which will grow as more states have low-carbon fuel standards in place," said Joe Lardy, a market intelligence analyst with **CHS Global Research**, the market insights arm of CHS, a global agribusiness owned by farmers, ranchers and cooperatives across the U.S. "There is good momentum and there is good investment. It is coming in the foreseeable future."

How soon it happens largely comes down to policy. "Policy will be a driver of adoption, especially the implementation of state-by-state low-carbon fuel standards," added Dan Mauer, CHS Washington representative who meets with legislators and industry groups to advocate for a stronger renewable fuel policy.

continued

Farmers adjust in response to emission regulation

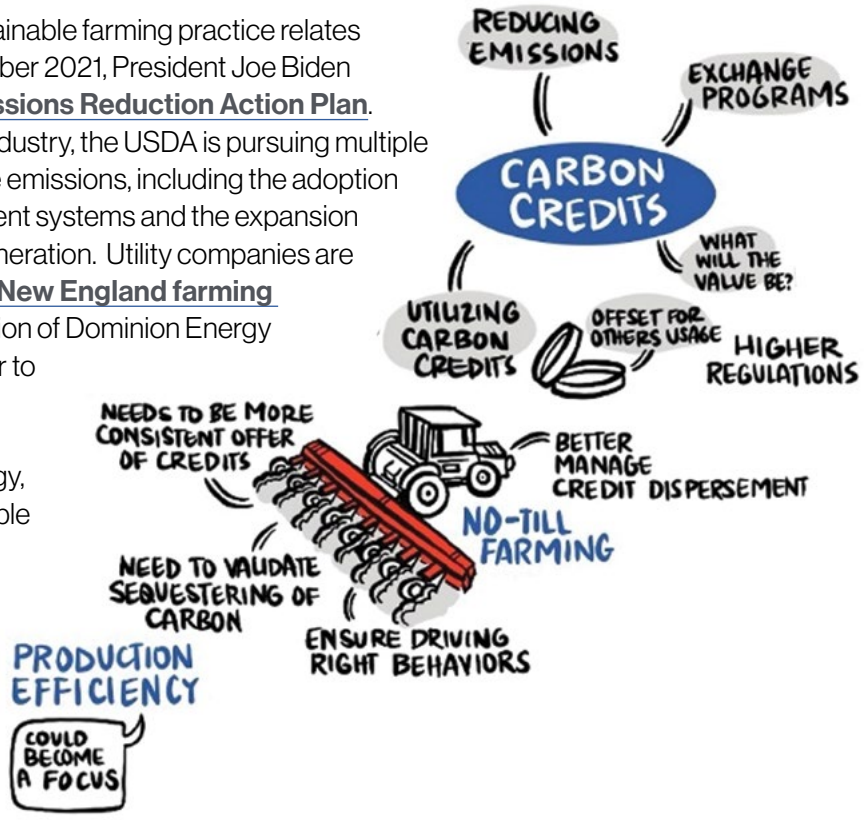
continued

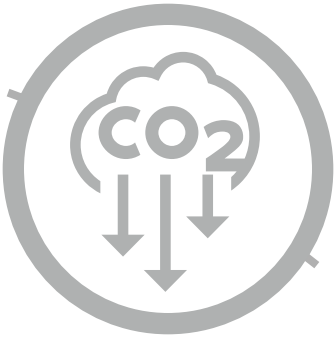
Assistance from government agencies will also help accelerate adoption of more sustainable farming practices. For instance, the USDA recently announced that it will be making a $1 billion investment in **pilot projects** that create market opportunities for U.S. agricultural and forestry products that use climate-smart practices.

"Through Partnerships for Climate-Smart Commodities, the USDA will provide targeted funding to expand market opportunities for climate-smart commodities that increase the competitive advantage of American producers," said U.S. Agriculture Secretary Tom Vilsack. A "climate-smart commodity" is defined as an agricultural commodity that is produced using agricultural practices that reduce GHG emissions or sequester carbon.

Another example of a more sustainable farming practice relates to methane emissions. In November 2021, President Joe Biden unveiled the **U.S. Methane Emissions Reduction Action Plan**. With respect to the agriculture industry, the USDA is pursuing multiple workstreams to reduce methane emissions, including the adoption of alternative manure management systems and the expansion of on-farm renewable energy generation. Utility companies are already working with farmers. A **New England farming operation** has caught the attention of Dominion Energy which is investing in their digester to expand it to other states.

This type of management strategy, along with a shift toward renewable energy-powered facilities and equipment, will help farmers keep pace with national emissions-reduction goals. In some instances, new revenue-generating opportunities will also be created.





8 Efforts to decarbonize create adjacent economies

As the trend toward carbon emissions reduction continues, standardized and regulated carbon marketplaces will be established, providing an opportunity for farmers to create a new revenue stream while continuing to lead the way on environmental sustainability.

There are already examples of government-sponsored carbon markets in other agriculture economies around the world. For instance, the Canadian province of **Alberta** has created a marketplace that allows regulated industrial operations to purchase carbon offsets from unregulated industries, including agriculture. To create carbon offsets, agriculture operations can utilize four of Alberta's 19 government-approved protocols: conservation cropping, GHG emissions reduction from fed cattle, renewable energy generation and distribution, and biogas.

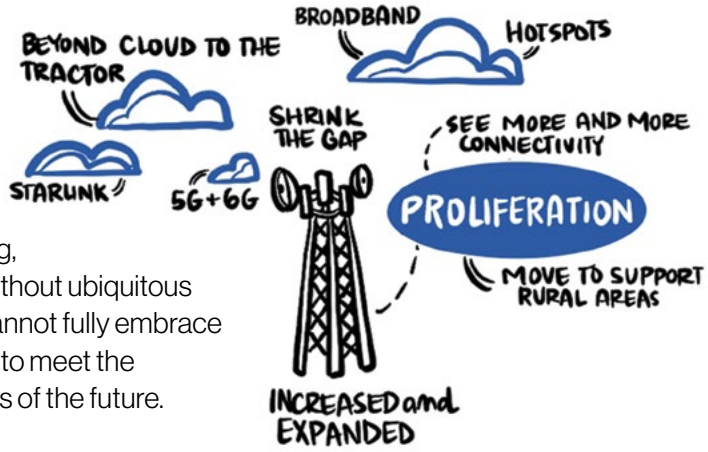
The **USDA** points out that there are also examples of carbon markets being established here in the U.S. For example, Land O'Lakes subsidiary Truterra has developed its farmer-owned **TruCarbon** program that helps farmers generate and sell carbon credits to private sector buyers. Credits can be generated by adopting **certain practices** such as no-till, strip-till, reduced-till and continuous soil cover. Truterra says its program paid $4 million to farmers for 200,000 metric tons of carbon in 2021. Payments ranged from an average of $20,000 to as high as $100,000.

THE TRUCARBON PROGRAM PAID $4 MILLION TO FARMERS FOR 200,000 METRIC TONS OF CARBON IN 2021

With Europe further along in their development of these types of policies, it could help create some momentum by serving as a model for the U.S. What is certain is that data will become a farmer's best friend, helping to document the results of their practices which create tremendous value in a carbon marketplace. Subsidies will also be influential in fostering widespread adoption of technology farmers will need. Over the next 10 years, significant momentum will be gained, and American farmers will have the opportunity to be rewarded for their ongoing commitment to environmental conservation.

9 Connectivity gap narrows

A multi-faceted strategy including fiber optic, LEO (low earth orbit) satellites, 5G and ultimately 6G will continue to close the rural connectivity gap, enabling farmers to leverage the myriad of technologies and management strategies that will help them produce more with less environmental impact.



Connectivity is the lynchpin of agriculture's future. Connectivity enables game-changing technologies such as PA, soil and weather sensors, AI including machine learning and machine autonomy, equipment tracking, food traceability and so much more. Without ubiquitous connectivity, the agriculture industry cannot fully embrace the new technologies that will enable it to meet the productivity and sustainability demands of the future.

As it stands today, just **one-quarter of farms** in the U.S. currently use connected equipment or devices to access data. A lack of broadband-related infrastructure is a big reason why. According to the FCC's **2020 Broadband Deployment Report**, 22.3% of Americans in rural areas lacked coverage from fixed terrestrial 25/3 mbps broadband at the end of 2018, as compared to just 1.5% of Americans in urban areas. Since then, the FCC has continued efforts to accelerate deployment of advanced telecommunications ability and close the digital divide. However, that 2015-2016 standard has fallen out of date. Today's standard for wireless connectivity is 100/20 mbps, a considerable improvement. The USDA is beginning to devise new rules around this higher standard, underscoring the importance of establishing modern broadband infrastructure in rural areas.

THE 2021 BIPARTISAN INFRASTRUCTURE LAW INCLUDES $65 BILLION TO IMPROVE INTERNET SERVICE

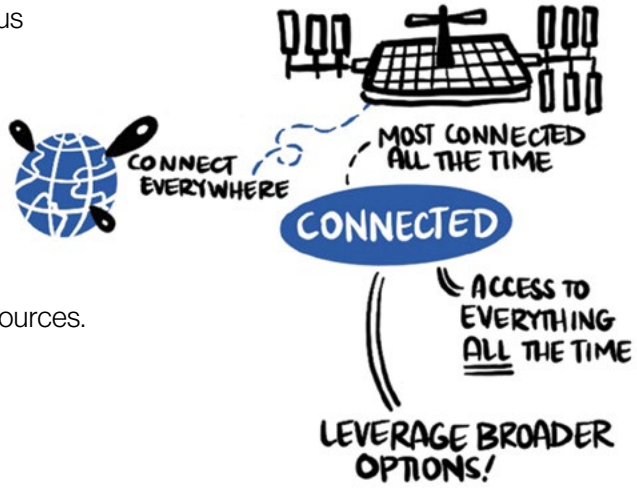
The 2021 Bipartisan Infrastructure Law is an encouraging start. It includes **$65 billion** to improve internet service to rural areas, low-income families and tribal communities. Most of the money will likely be made available through state grants. From there it becomes a matter of policy priorities. The opportunity is here to prioritize connectivity for the essential food supply chain across rural America versus entertainment streaming speed.

continued

Just one-quarter of farms in the U.S. currently use connected equipment or devices to access data

Initiatives such as the USDA's Broadband ReConnect program are designed to assist. ReConnect provides loans and grants to eligible rural areas that lack sufficient access to broadband. Additionally, many states have developed their own **grant programs** that are helping to deploy broadband to rural areas where it would otherwise be economically infeasible.

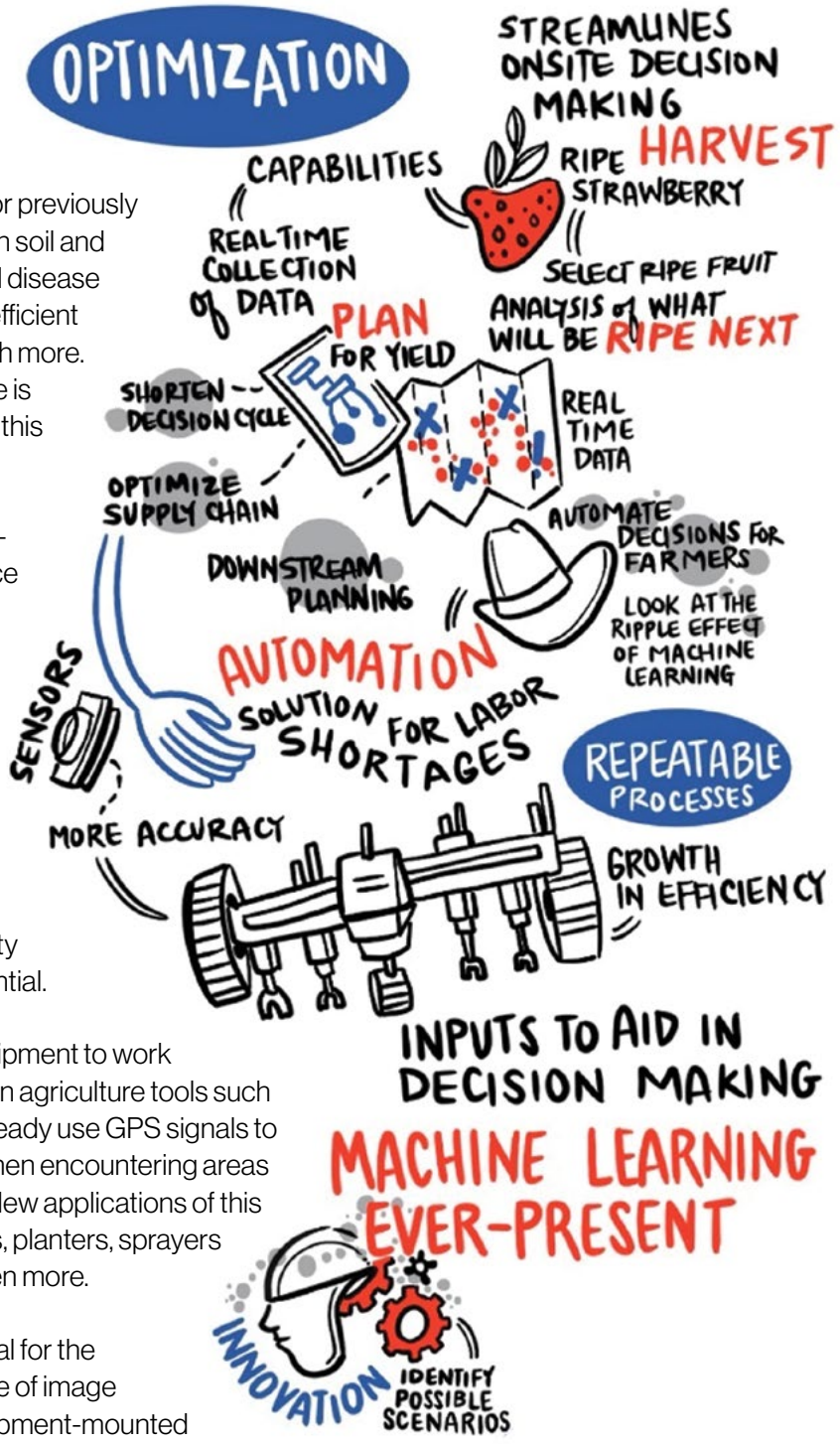
Over the next 10 years, there is a tremendous opportunity for the agriculture industry to take significant strides to close the connectivity gap. As reliable internet access becomes more available, the leveraging of cutting-edge technologies becomes more practical, leading to a transformative shift in agriculture practices that drive productivity while conserving resources.



10 Artificial intelligence enables insights-driven farming

Artificial intelligence, including a predominance of machine learning and precision agriculture, will continue to revolutionize the agriculture industry, allowing for previously unimaginable advancements in soil and water management, weed and disease detection, yield predictability, efficient equipment operation and much more. The skilled workforce shortage is one of several drivers spurring this innovation.

The agriculture industry is well-suited to maximize the influence of large amounts of IoT data. AI applied to machines automates the data analysis process providing farmers with insights and recommendations to help improve and streamline decision making. That data capture and analysis can also provide deeper food traceability insights that will become essential.



Machine learning enables equipment to work smarter. For example, precision agriculture tools such as machine section control already use GPS signals to turn planters or sprayers off when encountering areas that don't need to be treated. New applications of this technology will enable tractors, planters, sprayers and other equipment to do even more.

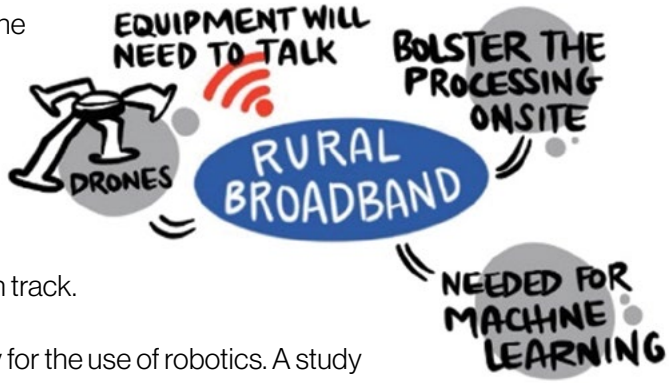
A key to the enormous potential for the agriculture industry is in the use of image recognition. For example, equipment-mounted cameras can scan large fields for targeted areas

continued

Artificial intelligence enables insights-driven farming
continued

showing signs of pest infestation, plant disease and weed presence. Artificial intelligence connects these inputs, along with infrared imagery and in-ground sensors, to help analyze growing conditions and predict their effect on crop yield. All of these insights can help farmers make real-time plant-level decisions, resulting in maximum yields with fewer inputs and environmental impact.

Beyond supporting crop production, machine learning can improve equipment management to help predict maintenance, repair and replacement needs before costly downtime occurs. Timing is everything for growers, and equipment reliability with machine learning provides operational feedback to keep production on track.



Machine learning also presents opportunity for the use of robotics. A study presented by **Science Direct** highlights the fact that nearly 70% of food product loss results from something other than decay, such as improper packaging or harvesting. Auto-harvesting robots utilizing machine learning can scan fruit and determine if it is harvestable. Studies show that robots can detect 90% of harvestable fruit and harvest it in just 16 seconds, much faster and more reliably than a human can.

Studies also show that, although more capital-intensive upfront, autonomous equipment can help farmers improve profitability. Results of an **economic feasibility assessment** illustrate a 24% increase in net returns when including both input savings and yield increase due to reduced compaction (since autonomous equipment can generally be smaller and lighter). Additionally, autonomous equipment will help farmers address the shrinking workforce they are facing.

> **Beyond supporting crop production, machine learning can improve equipment management to help predict maintenance, repair and replacement needs before costly downtime occurs**

Over the next 10 years, artificial intelligence, including machine learning, will begin to assume a prominent role throughout the entire crop-producing process, helping farmers make better crop management decisions, conserve resources and improve the way they plant, manage and harvest their crops. At a time when farmers will be asked to produce more with less impact, artificial intelligence including machine learning will prove to be invaluable.

11 Resources pour into cybersecurity

As agriculture operations become more connected, they inherently become more vulnerable. A sharp and sustained increase in cybersecurity investment will help ensure that vital equipment, sensors, data, infrastructure and food supplies remain protected.

Infosecurity Magazine reported on an Australian researcher who spoke at the DEF CON 29 Conference in August 2021. The researcher explained that as modern farming becomes increasingly automated, equipment becomes vulnerable to hacking. A hacker could potentially turn off spraying equipment, for instance, or even send a tractor off course and out into a road. In less theatric fashion, a hacker could simply gain access to equipment user information and other sensitive food supply chain data.

Cybersecurity extends beyond connected equipment, though. Data will become increasingly vital as artificial intelligences drives the decision making of the future. Not only will sensors, cameras and other connected devices need to be protected, but also the servers housing all of the data.

Case in point, a large **global meat processing company** recently paid $11 million after undergoing a ransomware attack. The hack forced meat plants across the U.S. and Australia to shut down for at least a day. In a statement, the company indicated that while it was able to get most of its systems running without the hacker's concession, it chose to pay the ransom to keep its files safe.

The concept of the Internet of Things (IoT) is still relatively new. But its potential to positively impact the way industries function is well recognized. IoT is now ranked as **strategically important** by each of the major U.S. federal agencies that focus on increasing competitiveness, economic prosperity and national security. That is a good sign that points to robust research and investment into cybersecurity. In fact, the federal government has allocated $1 billion of the recent $1.2 trillion infrastructure bill for cybersecurity funding, as reported by **StateTech magazine**.

continued

Resources pour into cybersecurity *continued*

The National Institute of Standards and Technology (NIST) is helping to lead the IoT cybersecurity effort. NIST's Cybersecurity for the Internet of Things **program** supports the development and application of standards, guidelines and tools to improve the cybersecurity of connected devices.

More companies will adopt a **Zero Trust** strategic approach to IoT device security. Zero Trust assumes there is no implicit trust granted to assets or user accounts based solely on their physical or network location, nor their asset ownership. Authentication and authorization (both subject and device) are discrete functions performed before any connection to an enterprise resource can be established.

> **As modern farming becomes increasingly automated, equipment becomes vulnerable to hacking**

Another important cybersecurity initiative is FedRAMP, a government-wide program that leverages NIST standards and guidelines to provide standardized security requirements for cloud services used by federal agencies. In other words, when a cloud service earns FedRAMP approval, you know it's trustworthy and reliable to use.

Food security has many elements of risk, and the role of cybersecurity in the food supply chain is intensifying. It will be important for the agriculture industry to seek out cybersecurity resources.

12 Farm ownership models change

The decoupling of land ownership and farm operation will accelerate over the next decade, resulting in a farmland ownership profile skewed toward landlords.

According to **USDA ownership data** from 2017, just under 40% of total farmland is rented. Of that rented farmland, 80% is owned by non-operator landlords, and 38% of those non-operator landlords are retired farmers. Data presented by the **American Farmland Trust** adds further perspective. Roughly 41% of U.S. farmland is owned by people at least 65 years old. In other words, roughly 370 million acres of farmland will likely be transitioned over the next 10 years.

Owner-operators are still expected to own a significant amount of America's farmland. However, new investors are expected to claim an increasingly sizable share. As farmland is passed down within families, subsequent generations are less likely to maintain ownership. This creates an opportunity for various types of investors to acquire an asset that provides them with attractive returns over time.

As reported by **Successful Farming**, among the top landowners in the U.S. are lumber producers, media executives and a professional sports team owner. Additionally, software tycoon **Bill Gates** has become the largest private owner of farmland in America. **Foreign holdings** of U.S. farmland are also on the uptick, increasing 2.2 million acres per yea from 2015-2020, more than double the annual pace seen during the 2008-2015 timeframe.

Farmland REITs (real estate investment trusts) are beginning to amass significant wealth. For instance, Gladstone Land owns 105,000 acres across 14 states, renting to 79 different tenants. Farmland Partners owns 157,000 acres across 16 states, renting to 100-plus tenants. (Data as of August 2021.)

As landlord-owned farmland increases over the next 10 years, landlords will be looking to make the best use of this valuable asset to maximize their ROI. As Farmland Partners' corporate profile states, "We work with our tenant base to lower their input costs and improve our farms, as a result increasing both their profitability and ours." To that end, growers will be encouraged, if not required, to take the necessary steps to increase productivity while reducing inputs and environmental impact.

The value of a grower's leadership, knowledge and expertise in productivity and efficiency will be key to successful partnerships with new landowners.

13 New business models emerge

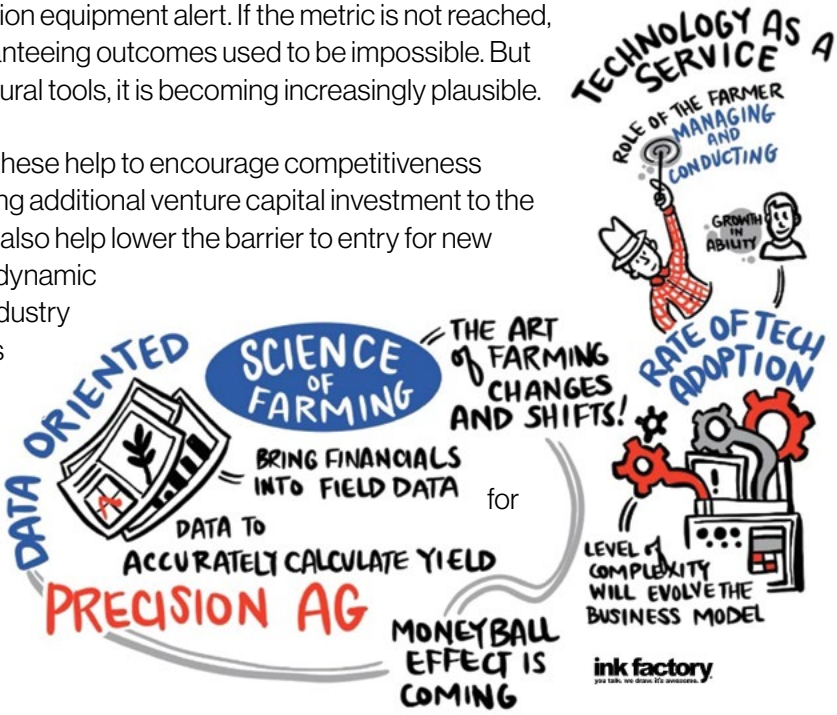
With the convergence of the 12 trends previously discussed, several new business models will emerge in the agriculture industry. Equipment manufacturers and dealers will reassess their value propositions, while farmers will gain an opportunity to reinvent themselves and pivot some of their risk.

One new business model relates to equipment acquisition. As technology and equipment advancement increasingly go hand-in-hand, farmers will see value in shifting equipment from capital expenditure to operating expenditure. Equipment as a Service (EaaS), for example, gives farmers an opportunity to lease equipment for a specified period. Payment is based on the output of that equipment along with any other services that go along with it, such as data analytics and preventive maintenance.

Custom farming will become another increasingly popular business model. **Custom farming** allows growers to farm more acres without assuming the additional risk of owning or leasing more land. Custom farming also allows growers to maximize equipment utilization and develop specialties in certain areas, helping drive productivity and profitability while keeping capital expenditures in check. The custom farming model also allows landowners to manage their farmland while allowing someone else to perform much of the work. Over the next 10 years, as farm equipment becomes more sophisticated and land ownership shifts toward non-operator landlords, custom farming will prove to be a win-win solution for many agriculture industry stakeholders.

Another transformative shift will be **outcome-based pricing models**. Several companies have already introduced programs that guarantee a certain metric or outcome, such as a yield goal, disease-free field or irrigation equipment alert. If the metric is not reached, farmers receive a refund. Guaranteeing outcomes used to be impossible. But thanks to today's digital agricultural tools, it is becoming increasingly plausible.

New business models such as these help to encourage competitiveness which spurs innovation, attracting additional venture capital investment to the industry. New business models also help lower the barrier to entry for new players, fueling an increasingly dynamic marketplace. The agriculture industry has long been driven by families and owner-operators who farm simply because they love to farm. Over the next 10 years, that same love farming and preserving the environment are what will usher in a new era of agriculture—an era based on producing more with less.



Conclusion

America's farmers have always met the challenges of their time. Now, with global populations rising, food demand increasing, a shrinking skilled workforce and the need for environmental conservation becoming more urgent, the bar has been raised once again. Make no mistake, farmers will answer the call through innovation.

Vastly improved rural connectivity will enable game-changing technologies that farmers enthusiastically embrace. Farmers will also lead the way on sustainability, from water conservation and renewable energy production to the creation of carbon offsets through sustainable agriculture practices. The world is changing, food production is changing, and even the complexion of farmland ownership in America is changing. Over the next 10 years, the one constant at the center of it all will be the American farmer, blessed with the ingenuity and tenacity needed to continue ensuring a reliable food supply here at home and abroad.

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Several of the vision team meetings were documented with visual notes by **Ink Factory**, portions of these are used throughout the document.

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