Agricultural Disruption

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New technology, consolidation, may yield production gains, job upheaval

A rtificial intelligence (AI) is poised to dramatically change agriculture around the globe. New technologies are likely to increase food production and sustainability. But millions of small-scale farmers and seasonal laborers could lose their occupations to robots that would perform repetitive, routine tasks. How these farmers and migrant workers will find new livelihoods is not addressed by agricultural disrupters.

“Robots won’t take all jobs at once,” says Evan Fraser, a food-security researcher and geographer at the University of Guelph in Ontario, Canada. Workers will collaborate with automating machines for simple tasks and later for more complex ones. “Automation will supplement the tasks of many workers at first; only later will machines replace them.”

Agriculture is probably the least automated economic sector in the world. But just as advanced digital tools are transforming healthcare, they will revolutionize farming, initially in high-income countries, where the process is just beginning. “Even in Canada and the US, we’re just scratching the surface of what can be done,” says Fraser.

Digital agriculture—or “smart farming”—is advancing through the use of improved sensors, more-accurate computer vision systems, and powerful AI. Someday, large-scale farms will use remote and built-in sensors, cloud storage in digital warehouses, AI software to analyze huge volumes of data, and algorithms to guide machinery. Automated farming systems could grow more bountiful crops on the same acreage at lower cost while using smaller volumes of pesticides,
Smart farming, then, is expected to help meet the rising demand for food in more sustainable ways.

Global demand for agricultural products is expected to grow 50 percent from 2005/2007 levels to 2050 levels to meet population growth, a rising middle class in many nations, and greater demand for meat and other animal protein, according to the United Nations report, “World Agriculture towards 2030/2050: The 2012 Revision.” Artificial intelligence could be an important tool in addressing this looming agricultural crisis. At the same time, many of the benefits of these new technologies could go to the wealthiest farmers. For others, including millions of small-scale farmers and migrant workers, the impact could be devastating.

More than 50 percent of farm tasks are both physical and predictable—and likely to be automated, according to “A Future that Works,” a December 2017 report by McKinsey and Company. But societies both past and present have experienced similarly wrenching workforce challenges and adapted successfully. In 1850, agriculture employed about half the US workforce; in 1970, that figure was only about 5 percent. New kinds of jobs in expanding industries, particularly urban manufacturing, eventually replaced most farm work.

Other countries have transitioned from rural to urban societies even faster. One-third of China’s workforce moved out of agriculture between 1970 and 2015 when young people flocked to cities to find low-skilled manufacturing jobs. But that work rung could weaken as factories automate and urban employment requires further education and training. Some developing economies are struggling to create jobs for growing urban populations of more educated workers.

Smart farming will change what farm workers do as well as where many do it. “Automation in agriculture is taking away low-paying jobs and replacing them with good-quality jobs in Canada,” says Fraser. A growing number of Canadian agriculture-related jobs are in information technology (IT), marketing, and telehealth veterinary services. Says Fraser, “If I’m a farmer with more spare cash because I’ve reduced my labor costs and increased productivity, I can do a better job of marketing my product and spending money on advertising or social-media marketing to give my milk, for instance, or other produce a more distinctive appearance to the public.”

But as agricultural work becomes increasingly autonomous, some tasks could be done remotely, which might not help rural economies that fail to attract workers with digital skills.

As automation improves, many smaller-scale farmers will probably continue to struggle, but migrant workers could be hit hardest first. “Automation could disadvantage people who are already very disadvantaged,” says Fraser. “These are typically very vulnerable people who depend on seasonal work as their main source of livelihood.”

The labor conundrum
Will workers arrive in time for harvest? That is the question that keeps many farmers up at night. Seasonal labor in high-income countries is becoming scarcer and more expensive because of tougher immigration laws and migrant-labor crackdowns. Many growers hope that advanced sensors and robotics could help augment a shrinking labor force.

Growers meanwhile are being squeezed by changing demographics, says Avi Kahani, CEO of Israel-based FFRobotics, which is one of the few companies developing apple-picking robots. “From Washington State and California to Argentina, to Israel and Poland and Italy, and even to India and China, I’m told, ‘Think about your own son. Would you let him go and pick apples or would you send him to the university?’”

Picking soft fruit is one of the hardest automation challenges in agriculture. Soft fruits—such as apples and pears—are easily bruised, so every apple sold on the global fresh market is still picked by hand. If robots became cheaper and more reliable, though, they would represent a major advance in farm automation. But many migrant workers would lose their jobs.
Each autumn in the United States, about 40,000 people pick and pack apples. Temporary migrant laborers constitute about one-third of this peak-season labor force. Most arrive on H-2A guest visas, though an unknown number of seasonal workers are undocumented. Growers complain that the guest visa system is confusing, bureaucratic, and unreliable.

After years of field tests, FFRobotics plans to introduce its apple-picking robots into Argentinean orchards in March 2020 and in Washington State for autumn harvest. The six-arm robot, sitting on a human-driven tractor, is expected to pick 90 to 95 percent of apples, and small numbers of human laborers would follow behind to pick the rest, says Kahani.

Kahani’s apple-picking robot uses cameras and facial-recognition software to identify fruit. Nearly all of today’s commercial facial-recognition systems are based on artificial neural networks or “deep learning” software. FFRobotics trained its software by feeding it huge numbers of labeled digital images of apples. The software learns how to recognize certain features—color and shape and orientation—of each apple’s “face.”

The software is also trained to identify leaves and branches and other orchard background details. Over time, the program learns to differentiate confounding backgrounds from apple faces. Eventually, the system begins self-teaching, improving its own ability to recognize an individual apple. Finally, programmers train the robot’s arms to move toward identified apples and pick them with gently grasping “hands.”

Robot pickers are feasible only in modernized orchards. A traditional apple tree has branches that grow randomly and crookedly in many directions. Many apples hide in shadow or behind limbs and leaves—details that confuse facial recognition systems. Over the past decade, geneticists have improved designs of dwarf tree varieties that growers prune and thin to create simpler canopies. Limbs grow in vertical planes or V shapes along orchard rows. In a “fruiting wall” canopy, apples are less obstructed from view and reachable within the length of the human arm. These simplified canopies also allow a robot a better chance of identifying and picking apples. Orchards annually remove some aging trees and plant new ones, but it can take decades for a grower to transition entirely to a fruiting-wall...
system. To afford high-tech robotics, some larger orchards are likely to buy up smaller ones, consolidating production into fewer hands.

Joshua Haslun, lead agriculture analyst at Lux Research, a technical innovation consulting firm, is doubtful about FFRobotics’ 90-to-95 percent picking efficiency hopes for 2020, even in modernized orchards. “Fifty percent of the harvest by a commercially viable apple picking robot is the best-case scenario by 2020,” he says.

Changing sunlight, shadows, weather, and dust tend to confuse even sophisticated computer vision systems. “When you’re out there in the field, the vision system is difficult to control and it misidentifies things and makes mistakes,” says Shiriram Ramanathan, who leads the big data analytics practice at Lux Research. “Most success stories with deep learning systems and robotics in agriculture are in controlled settings. Operating inside a greenhouse is a much, much better option.”

Smart tools monitor climate conditions and disease

Indeed, smart farming’s leading edge is indoors—in milking barns, cow sheds, chicken houses, and particularly in industrial-scale greenhouses. Facial recognition software and cameras mounted in cow sheds are already helping farmers identify individual cows and indicators of sickness or injury. Farmers can treat livestock sooner, protecting their investments. Around 50 percent of all European herds will be milked by robots by 2025, according to a 2018 whitepaper by the UK-RAS Network, an academic–industry collaboration. Robots are starting to remove waste from cattle cubicles and move feedstuffs, as well.

Cameras and other sensors in industrial greenhouses monitor temperature, plant and stem density, soil moisture, and other parameters. By manipulating climate factors, managers can increase yields with fewer resources, growing up to 10 times more fruits and vegetables than open fields, with much less water. Some advanced greenhouses deploy AI and sensors to analyze which seeds produce healthier yields under different climate conditions. Someday, self-learning software could largely take over greenhouse management, crunching data to determine the optimum climate and other needs for particular crops. Computers would instruct robots when and where to plant and pick produce. Growers could manage greenhouse systems from anywhere in the world, although IT workers would be needed on site to tune algorithms and monitor and repair equipment.

Farm automation outdoors is moving in a similar direction, albeit more slowly. In 2016, autosteer tractors accounted for 10 percent of the US market, and that share is expected to increase, according to Lux Research. (The report is proprietary. This information is from a press release.) Small robots are thinning young lettuce buds and trimming wintertime grape vines. Robotic vision systems can “see” spring lettuce plants more accurately against dirt backgrounds that are free of early weeds. Wintertime grape vines have lost leaves that can confound a robot’s vision.

For the past decade, farmers have increasingly used data from aerial sensors—drones, airplanes, and satellites—to identify crop diseases and estimate potential harvests. For instance, hyperspectral images from aerial sensors can illustrate ground moisture and heat as color-coded images. The most advanced aerial sensors are typically used by very large agricultural operations on broad, flat fields of monoculture row crops such as corn or soybeans. Advanced sensors typically are not affordable for small, isolated farms on varied or hilly terrain that grow a patchwork of different crops and livestock. “Larger farms,” says Haslun, “are more likely to have the funds, insurance, and credit to decrease their risk as they try new technologies.”

The shift by individual growers to automation will be determined largely by costs and availability of labor for different crops and places. For instance, if shared by multiple farms, experimental strawberry-harvesting robotics in Japan nearly match the cost of human labor. But robots there will have an advantage. The average Japanese agricultural worker is 67 years old—and more than 70 in highland regions.
Consolidation, automation, and export-oriented markets

Some nations are consolidating farmland to improve agricultural efficiency, guarantee future food supplies, create more profitable exports, and set the stage for automation and robotics. China, for instance, has undertaken a sweeping land-consolidation program to improve food production, and its universities are among global leaders in artificial intelligence research in agriculture.

After the collapse of the Soviet Union, Russia's farm sector continued to sputter. In the early 2000s, the Kremlin began an initiative to turn Russia into a global superpower in agriculture. Over the past 15 years, Russia's federal, regional, and municipal governments and private companies have merged thousands of former collective farms into nearly 800 mega farms, each of which can comprise hundreds of thousands of hectares. Megafarms have become more productive, more profitable, and economically far stronger than midsize and smaller ones, according to an October 2018 study in the Journal of Agrarian Change by Stephen K. Wegren, a political scientist at Southern Methodist University.

“Megafarm holdings are tied to political leadership both regionally and federally, and they receive the bulk of credits and subsidized loans,” says Wegren. “These farms are both vertically and horizontally integrated, so they control all stages of the production cycle.” Horizontal integration occurs when, for instance, a seed-and-pesticide company acquires another. Vertical integration occurs when a farm or seed-and-pesticide company has effective control over other stages of food production such as processing operations and distribution.

In 2019, Russian megafarms are slated to receive further federal subsidies to acquire robots for testing soils and monitoring production. Each robot is estimated to cost about 2.5 million rubles ($37,300) for farmers—far beyond the means of the average small or midsize farm operation.

The Russian federal program aims to recruit 90,000 IT specialists to help megafarms integrate robotics into production.

Russia meanwhile is aggressively investing in greenhouse farming. In 2014, the Russian government initiated a boycott of all fruit and vegetable imports from European Union countries after being slapped with sanctions following the invasion of Crimea. “The Kremlin is developing industrial greenhouses to produce cucumbers and peppers and tomatoes that they won't have to import,” says Wegren.

The federal government created a support program for high-tech

Further reading.


greenhouse projects, making it possible for investors to get up to 20 percent financial support for their project, although the subsidies will end this year.

Subsidized industrial greenhouses are taking over market share from microscale “peasant” farming. A special farmer class—known in the post-Soviet era as lichnoe podsobnoe khoziaistvo—is limited by law to plots smaller than 2 hectares, which is the most common farm size in many regions around the world.

In Russia, lichnoe podsobnoe khoziaistvo are typically operated by families who have other sources of income. While small in size, they have had an outsized role in Russian agriculture, historically growing many of the country’s vegetables. But their share of production has been in decline, Wegren says. “Against industrial greenhouses, I don’t see how they will be able to compete anymore.”

**Mega-mergers threaten farmer autonomy**

The 2008 global recession battered industrial agriculture, dimming crop prices and revenues. Lower prices led to belt tightening and mega-mergers, which further concentrated global market shares in fewer hands. Now, instead of six global food and agriculture businesses, there are only four. Bayer and Monsanto merged and became Bayer, now the world’s largest agrochemical, seed, and biotechnology firm. Dow and DuPont merged to become Corteva Agriscience. BASF expanded by acquiring parts of other agrocompanies. ChemChina and Syngenta merged into ChemChina/Syngenta, which could become part of Sinochem. These four companies control most of the supplies that farmers need to buy, including 67 percent of global market share of seeds and 70 percent of agrochemicals. Other companies control 41 percent of farm equipment, according to “Blocking the Chain,” a 2018 report by the ETC Group, a Canadian nonprofit organization, and European partners.

Meanwhile, large corporations, many of them publicly traded, and institutional investors have rediscovered farmlands as an undervalued asset, buying up smaller operations and consolidating tracts into mega-farms in Latin America, Eastern Europe, and Southeast Asia.

But these trends are not new. Land consolidation and the growing power of industrial agribusiness have been squeezing small farmers for decades, says Lorette Picciano, executive director of the Rural Coalition, a nonprofit based in Washington, DC. In the 1980s, grocery-chain mergers damaged the profitability of many small farmers. “Chains wanted to buy bigger volumes because that helps them cut costs. But smaller farmers couldn’t produce those volumes, so they didn’t get the same deals. To compete, some farmers bought out their neighbors, and that made it easier for them to get financing and credit approved.” But many small farms have been muscled out, their costs of production exceeding their earnings. Net US farm income has declined by half since 2013, and today, half of all farmers have negative on-farm income, says Picciano.

Meanwhile, global agricultural companies dominate farm data holdings and analysis. Global seed and pesticide businesses have signed contracts or licenses with the world’s largest farm machinery companies—such as tractor manufacturers—that provide the very digital platforms that farms need to participate in industrial agriculture.

Smart farming raises familiar questions about data ownership. “A lot of these data platforms are based in the tractors and other equipment, and they are linked to fertilizer and pesticide and seed data,” says Jennifer Clapp, a food-security scientist at the University of Waterloo in Ontario, Canada. By 2015, John Deere, a farm
machinery company, had agreements with companies then named DuPont, Bayer, and Monsanto, and also with BASF. Someday, giant agrocompanies could offer packages of data analytics with customized advice to farmers, crop protection products, and complementary genetically modified (GM) seeds. Farmers might get locked into planting GM crops if they take such contracts. Says Clapp: "With this leverage, global companies can say to farmers, 'If you sign onto this package deal, we can guarantee the size of your harvest,' and that serves almost as a kind of insurance for farmers. But will farmers retain rights to the data that arise from their own fields? If they don't own these data, what kinds of decisions could farmers actually make?"

Farmers in the future might have fewer opportunities to pursue agroecological farming practices such as intercropping and perennial crop rotations that reduce erosion and increase soil biodiversity. “There is a potential that all rural agriculture will become completely digitalized, reducing farmers’ autonomy,” says Clapp. “And that raises questions about the quality of life, the quality of work, for farmers and rural communities. If small producers can’t afford digital technologies, they may get bought out by larger ones who can, and that can contribute to wiping out the livelihoods of many millions around the world.”

Smart farming could face two potential extreme scenarios in data ownership and control, she says. At one extreme, a farmer would be forced to give up all rights to data controlled by a small number of organizations. At the other extreme, open data systems would allow farmers more flexibility to choose among technologies and business partners.

Global agriculture is moving in the first scenario’s direction. “We are aware of these giant data companies—Google and Amazon,” says Fraser. “But we also have companies in the ag sector that are not branded like Google and Amazon because they’re not present in our lives in that way, but they are also data companies, though many people don’t realize it.”

Some observers are less worried about global conglomerates penetrating every data corner of farm fields. Instead, they are more concerned that many rural communities will fall behind in digitizing. In the future, rural areas that prosper are more likely to have effective broadband services, capital, or government subsidies to help farmers integrate advanced technologies and gain access to workers with computer skills. About 14 percent of locations in the United States lack affordable high-speed Internet. The federal government and private investors should spend $80 billion to bring high-speed Internet—preferably fiber—to those locations, according to a January 2017 white paper, “Improving the Nation’s Digital Infrastructure,” by Paul de Sa, then chief of the Federal Communications Commission Office of Strategic Planning and Policy Analysis. “An accelerating investment in broadband is likely greater than from most other areas of infrastructure investment,” de Sa writes.

Global agribusiness mergers have resulted in fewer companies amassing more data and developing tools to help precision farming advance more rapidly. Meanwhile, other major food sectors—aquaculture farms and commercial fishing operations—will also automate their systems as improvements continue in underwater sensors, robotics, climate models, and AI software. In the future, who might most benefit—small and midsize producers or global companies that hold data and control data analytics? Smart farming could exacerbate wealth disparities between small farms and large-scale operations. The expanding local food movement could help small businesses to build stronger markets for their produce. But it seems clear that many farms and rural communities will struggle to benefit from the next boom in food production.

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