Will Artificial Intelligence and robotics usher in an era of sustainable precision agriculture?

cross midwestern farms, if Girish Chowdhary has his way, farmers will someday release beagle-sized robots into their fields like a pack of hounds flushing pheasant. The robots, he says, will scurry in the cool shade beneath a wide diversity of plants, pulling weeds, planting cover crops, diagnosing plant infections, and gathering data to help farmers optimize their farms.

Chowdhary, a researcher at the University of Illinois, works surrounded by corn, one of the most productive monocultures in the world. In the United States, the corn industry was valued at $82.6 billion in 2021, but it — like almost every other segment of the agricultural economy — faces daunting problems, including changing weather patterns, environmental degradation, severe labor shortages, and the rising cost of key supplies, or inputs: herbicides, pesticides, and seed.

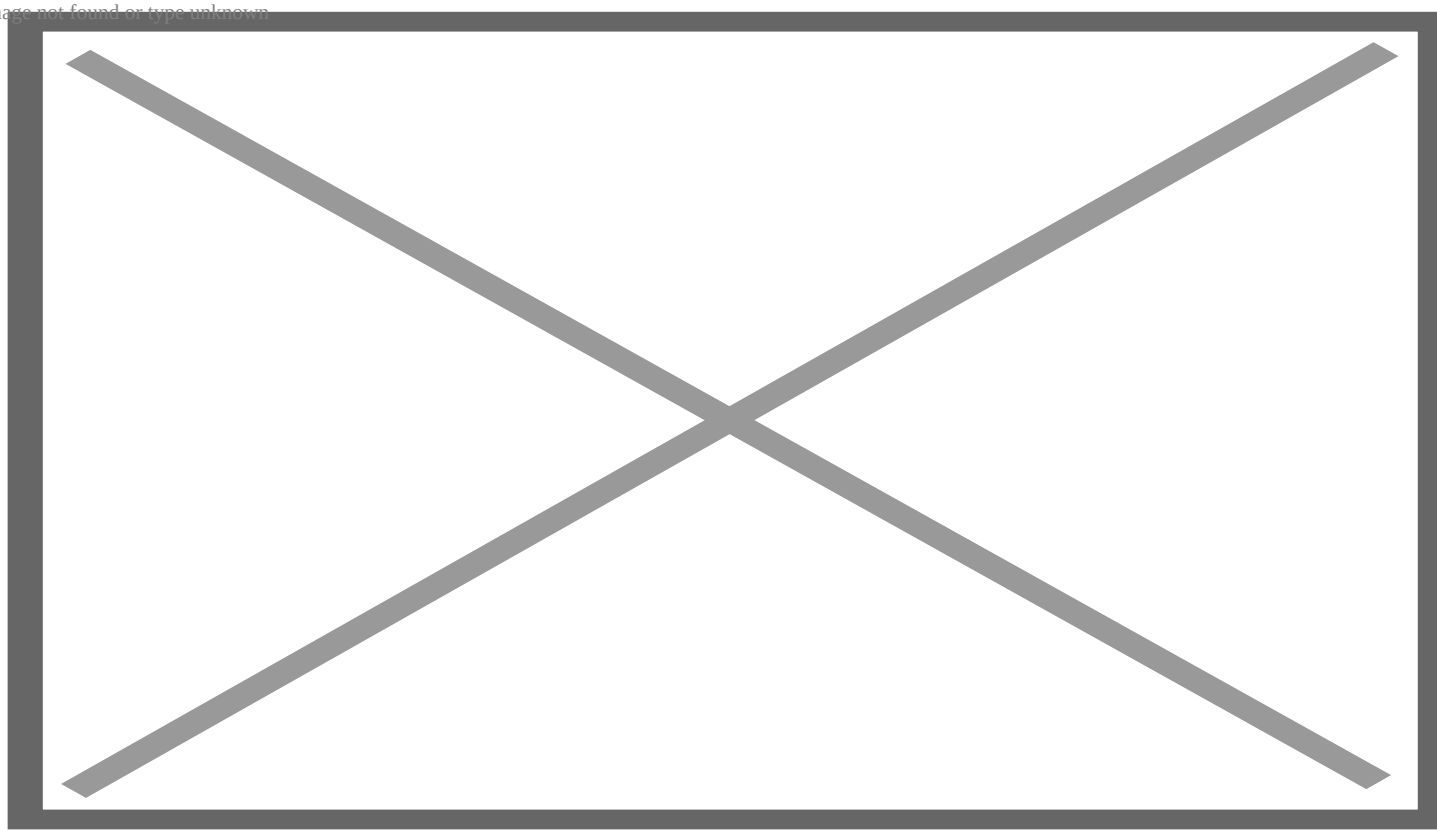
Agribusiness as a whole is betting that the world has reached the tipping point where desperate need caused by a growing population, the economic realities of conventional farming, and advancing technology converge to require something called precision agriculture, which aims to minimize inputs and the costs and environmental problems that go with them.

No segment of agriculture is without its passionate advocates of robotics and artificial intelligence as solutions to, basically, all the problems facing farmers today. The extent of their visions ranges from technology that overlays existing farm practices to a comprehensive rethinking of agriculture that eliminates tractors, soil, sunlight, weather, and even being outdoors as factors in farm life.

But the promises of precision agriculture still haven’t been met: Because most of the promised systems aren’t on the market, few final prices have been set and there’s precious little real-world data proving whether they work.

“The marketing around precision agriculture, that it’s going to have a huge impact, we don’t have the data for that yet,” says Emily Duncan, a researcher in the Department of Geography, Environment and Geomatics at the University of Guelph in Canada. “Going back to the idea that we want to reduce the use of inputs, precision agriculture doesn’t necessarily say we’re going to be using less overall.”

Image not found or type unknown



The “OZ” field robot at a technology show in a field in northern Saxony. Credit: Getty Images

Even so, Chowdhary, who is co-founder and chief technical officer of Earthsense, Inc., the company that makes those beagle-sized robots, is hopeful that the adoption of his robots will propel farmers well past precision agriculture, to think about the business of farming in a whole new way. Right now, he says, most farmers focus on yield, defining success as growing more on the same amount of land. The result: horizon-to-horizon, industrial monocultures saturated with chemicals and tended by massive and increasingly expensive machinery. With the help of his robots, Chowdhary foresees a future, instead, of smaller farms living more in harmony with nature, growing a diversity of higher value crops with fewer chemicals.

“The biggest thing we can do is make it easier for farmers to focus on profit, and not just on yield,” Chowdhary wrote in an email to Undark. “Management tools that help reduce fertilizer and herbicide costs while improving the quality of land and keeping yield up will help farmers realize more profit through fundamentally more sustainable techniques.”

Chowdhary’s robots may help farmers cut costs by, among other things, pulling weeds that compete with corn. For centuries, farmers tamed weeds with hoes and plows. World War II gave rise to the modern chemical industry, and the herbicides it produced made farmers perceive weeds as a non-issue, leaving the ground beneath crops like corn unnaturally bare and vastly increasing the yield per acre, revolutionizing the farm economy.

Nature is persistent, however, and inevitably weeds evolved that resist herbicides. To compensate, suppliers blend powerful and increasingly expensive herbicidal cocktails and genetically modify seed to be chemically resistant. That agricultural arms race traps farmers in a cycle of rising costs, threatens precious water resources, and only works until, as Iowa farmer Earl Slinker puts it, “you go out and spray it one year and it doesn’t do anything.” The result is a smaller harvest, according to Slinker, which in the low-profit-margin business of farming can mean disaster.

The question that underlies all the theorizing is both economic and cultural: Are farmers going to buy in?

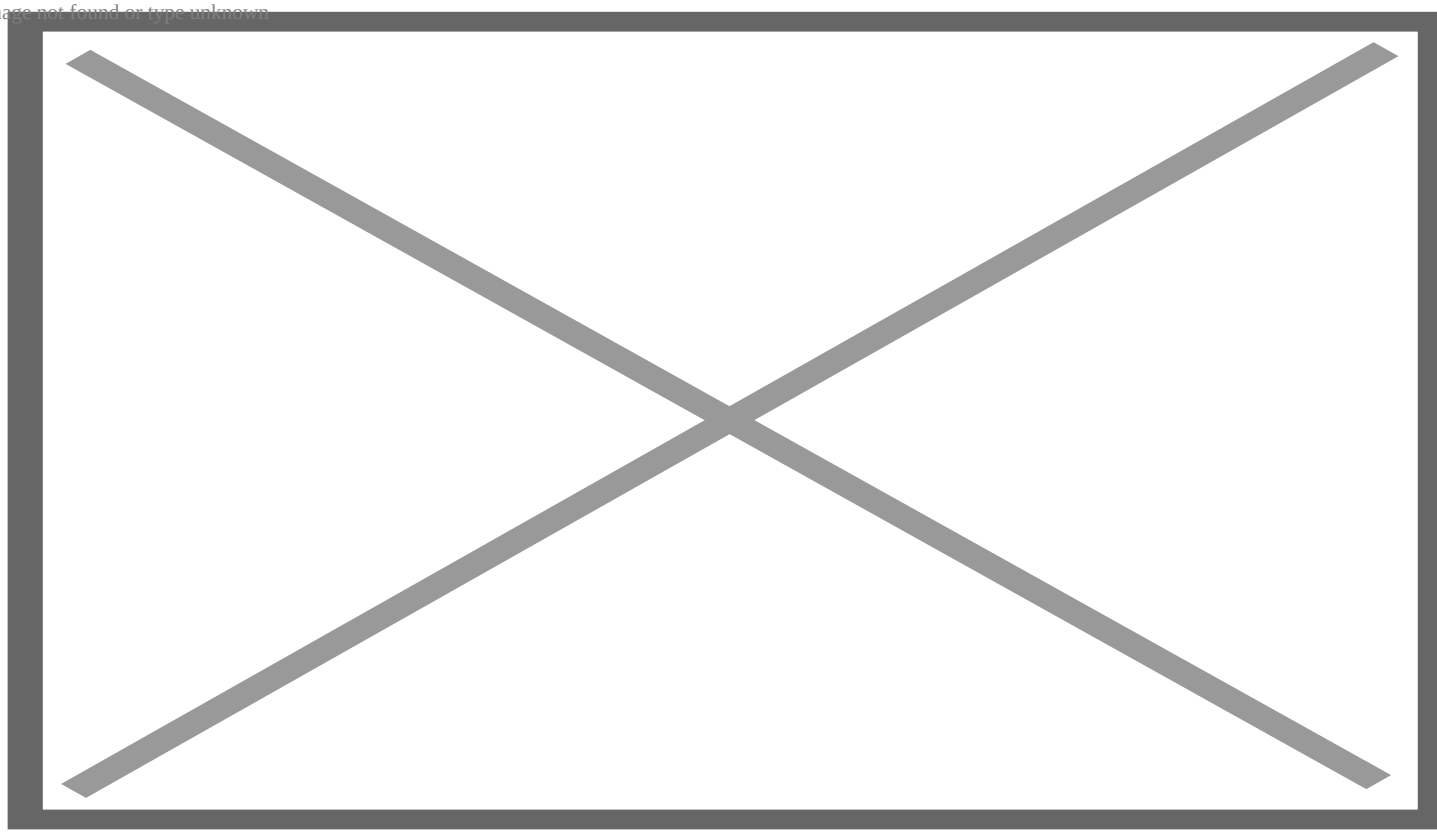
“The challenge is demonstrating the benefits to farmers and making these things easy to adopt,” says Madhu Khanna, who studies technology adoption at the University of Illinois Department of Agriculture and Consumer Economics. “For most of these technologies, the benefits are uncertain.”

In agriculture, the conventional wisdom is that the outcome of the race to the farm of the future will be determined by clear-eyed economic decision-making. If robotics and artificial intelligence make business sense, the market will develop. “Farmers and growers are very smart about that,” says Baskar Ganapathysubramanian of Iowa State University’s Artificial Intelligence Institute for Resilient Agriculture. “From hardware and software perspective, if there’s a clear value proposition,” he adds, “they’re going to choose it.”

The growth numbers suggest farmers are open to the potential benefits of advanced technology. Overall, farmers spent almost $25 billion on tractors and other farm equipment in 2020. While Covid-19 slowed the adoption of robotics, farms worldwide are expected to incorporate the technology into their operations faster than the industrial market — increases of 19.3 percent and 12.3 percent, respectively, over five years. The global research firm MarketsandMarkets estimates that spending on robots will go from nearly $5 billion in 2021 to almost $12 billion in 2026. One result of that optimism, according to CropLife, a U.S. agribusiness publication, is that the third quarter of 2021 saw more venture capital investment in agriculture technology startups than ever: more than $4 billion.

“So few people have experience with farming,” says Joe Anderson, an agricultural historian and professor at Mount Royal University in Calgary. “They assume there’s more stasis than there has been. There are lots of innovations. There have been lots of changes.”

Image not found or type unknown



Herbicide sprayer. Credit: Flickr

The tractors dragging huge implements across fertile fields feature technology that has outpaced even the most advanced automobiles. Many are steered by GPS, following paths mapped out over years of planting and harvest, rendering the farmer in the air-conditioned, video-equipped cab not much more than a passenger.

“You put your first pass and the next ones will follow right along,” says Slinker, who farms 500 acres outside Grundy Center, Iowa. “I just put on a little Keith Jarrett and sit back and travel across the field.”

In the autumn, harvesting machinery guides itself along those same tracks, sensing and recording the productivity of every square foot of field. That data can be used to calculate how much of which hybrid seed should be planted next year, determine how heavily it should be fertilized to reach its fullest potential, and identify small patches of ground that aren’t productive enough to be profitably planted.

“When I stop and think about an autonomous tractor, that seems like a really big leap,” Sarah Schinkel, who leads John Deere’s technology stack innovation group, said at the National Farm Machinery Show in February, “but when I stop and think about it and how much automation is already a part of our equipment, maybe it’s not that big of a leap.”

Deere is doing a limited release of its first fully autonomous tractor this year, with greater availability in 2023 and beyond. In contrast to the small-robot vision of researchers like Chowdhary, it’s a remake of the

company’s popular Model 8R tractor, which weighs 14 tons. It fits neatly into the existing agribusiness model, but even with that adoption advantage no one expects a fast transition. Farm equipment has an amazingly long lifespan, at least compared to consumer products like cars. Modern tractors routinely operate for 4,000 hours, and a well-maintained model can last 10,000 — or approximately 25 years.

“Even though you may think you’d be interested in getting some new robotic equipment,” says Scott Swinton, a distinguished professor in Michigan State University’s Department of Agriculture, Food, and Resource Economics, “a lot depends on where you are in the depreciation and use cycles for the equipment you have. So we see a lot slower adoption than you do in genetics or chemicals.”

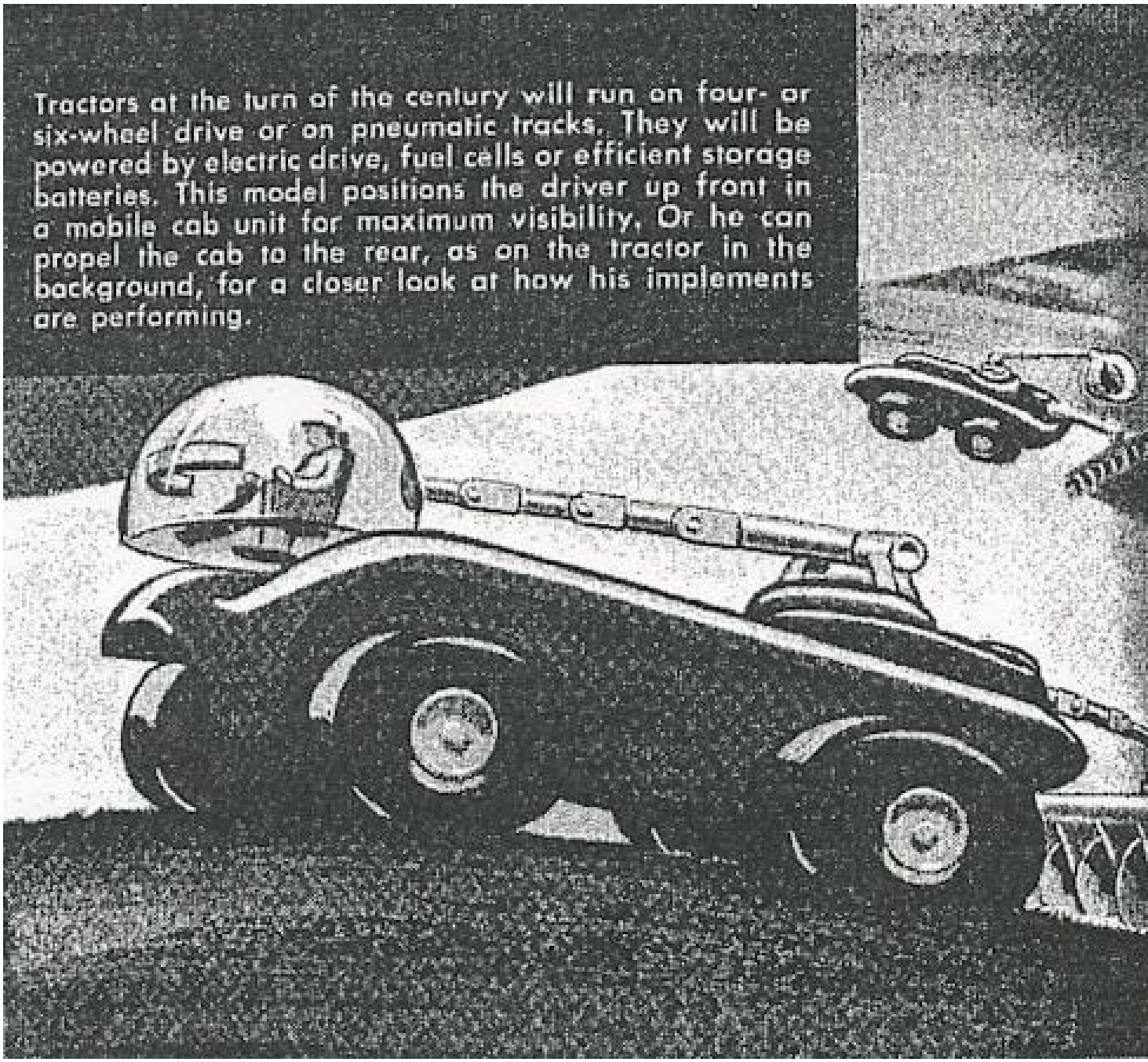
And there is another thing: Critics note that robotics, even if widely adopted, won’t address some of the underlying inadequacies of conventional agriculture.

“When we think about this global challenge of feeding everyone our current system is not set up to do that,” says Duncan. “The fix isn’t to throw more tech at it. It’s to question the system.”

The Midwestern corn-and-soybeans row-crop sector is just a fraction of all of agriculture, which in the U.S. was valued at over $205 billion in 2020. Much of that is what farmers refer to as horticultural crops — fruit, vegetables, and other produce.

“The important distinction is between field crops that are highly mechanized like corn and horticultural crops that require special treatment,” says Swinton. “They are higher value and can tolerate higher investments in equipment. It’s equipment that does weeding in vegetable crops, some robotic harvesting of, say, asparagus or broccoli, some robotic pickers of tree fruits. These are all in areas where you need somewhat skilled labor, and labor can be hard to get.”

The problem is, the planting and harvesting of horticultural crops that is handled so easily by people flummoxes robots. George Kantor, a research professor in Carnegie Mellon’s Robotics Institute, says it will be necessary to change farms to suit robots. Consider, he suggests, the unremarkable act of picking an apple. What a human laborer can accomplish almost without a thought is nearly impossible for a machine. Locating each piece of fruit, gauging its ripeness, and reaching through a tangle of leaves and branches to gently pluck it from the tree — it’s easier, he says, to train the tree than it is to train the robot. In the case of apples, that means sculpting the orchard into what he calls “fruiting walls”.



1968 depiction of a battery operated tractor. Credit: Kansas Farmer

“Their tree canopy is trained to be essentially a two-dimensional object,” Kantor says. “It’s a wall with a bunch of apples hanging off of it. We don’t have anything that can harvest your grandfather’s apple tree, that can reach inside the canopy and pick an apple. But these fruiting walls, it’s a much easier problem.”

Where the agricultural labor shortage is most intense, robotics are gaining ground the fastest. Robert Hagevoort, an extension dairy specialist and professor at New Mexico State University, says the nature of

dairy farming makes its labor crisis among the worst in agriculture's sectors. Cows need to be milked twice a day, he says, every day, creating a lifestyle that is a tough sell to young people choosing a career. The labor shortage is contributing to the decrease in the number of dairy farms.

"In some places," he says, "some of those producers with land they bought by the acre for agriculture end up selling it by the square foot for real estate development."

Robotics have offered a lifeline to some dairy farmers. But contrary to the idealized vision of smaller, more local, family farms, robotics have nudged dairy toward larger operations.

"If you went into farming because you wanted to do your own thing and be by yourself like my father did," says Christopher Wolf, professor of agricultural economics at Cornell University, "that's not the job anymore. It's a different skill set. You're going to be part of a management team."

Wolf grew up in Wisconsin at a time when 150 cows was a large herd, but still manageable by a single large family. Adding robots to dairy farming creates the same potential economies of scale that have industrialized row crops like corn and soybeans. A single robotic milker can care for over 60 cows, and the second milker is cheaper than the first, and the third cheaper than the second. In advanced milking parlors dozens of milkers can be linked together and managed by only a few technicians working predictable eight-hour shifts and having barely any contact with the cows.

"If you're set up that way you can also take a vacation," says Wolf. "I knew dairy farmers growing up who hadn't taken a vacation in 20 years."

At the farthest reaches of robotic farming are the developers who are completely abandoning almost every aspect of traditional farming. Iron Ox, a California start-up that just received a $53 million infusion of capital from Bill Gates' Breakthrough Energy Ventures fund, grows high-value fresh produce in completely controlled, indoor environments.

"Most approaches to automating parts of agriculture are one robot that does one operation," says Brandon Alexander, CEO of the company. "The reason that hasn't succeeded is at the end of the day plants are complex things. If you're really going to automate it, you have to design the entire process from the ground-up for automation."

That will likely happen first in an agricultural sector with few traditions to change, a very small installed technical base to replace, and a high rate of potential return — which is a pretty apt description of the embryonic cannabis industry. Legal cannabis is already the U.S.'s fifth most valuable crop, and producers are adopting new technology in ways traditional farmers are not.

"There's not a strong bias looking backwards at how the crop is produced," says Kantor. "The other thing of course is we talk about high value crops. Grapes are high value crops, leafy greens are high value crops, but cannabis is in a whole other league. It's going to drive a lot of interesting technologies."

A study by the University of Illinois estimates that the cost of seed, fertilizer, herbicides, and other farming inputs for corn and soybean production are going to rise over 30 percent between 2020 and the 2022

planting season. The study predicts per acre return — roughly the equivalent of gross profit — for corn will drop from $378 to $61 per acre in 2022.

“From a farmer’s perspective they know they need help,” says Alexander. “The average grower recognizes that something pretty drastic needs to change if we’re going to feed a growing population.”

But according to Terry Griffin, a cropping systems economist at Kansas State University, economists too often assume farmers will behave like businesses, when they often behave more like consumers. “Different people measure value differently,” Griffin says. “Some farm management goes to having the greatest net return. Some might want the newest equipment or the best environmental metrics. For every individual it’s a different value proposition.”

Khanna cites another factor that is often forgotten: consumer perceptions. If consumers start to demand, for example, more crops produced without today’s heavy application of chemicals, it could drive adoption of robotics.

Laser wielding robot that kills weeds. Credit: Carbon Robotics

“We underestimate consumers,” she says, in reference to the role they can play in creating this market. “As there is more demand for sustainably produced agricultural products, there will be a greater shift

toward documenting what farmers are doing. Policies will do that too, but a lot of the change is going to be driven by consumer and market pressures."

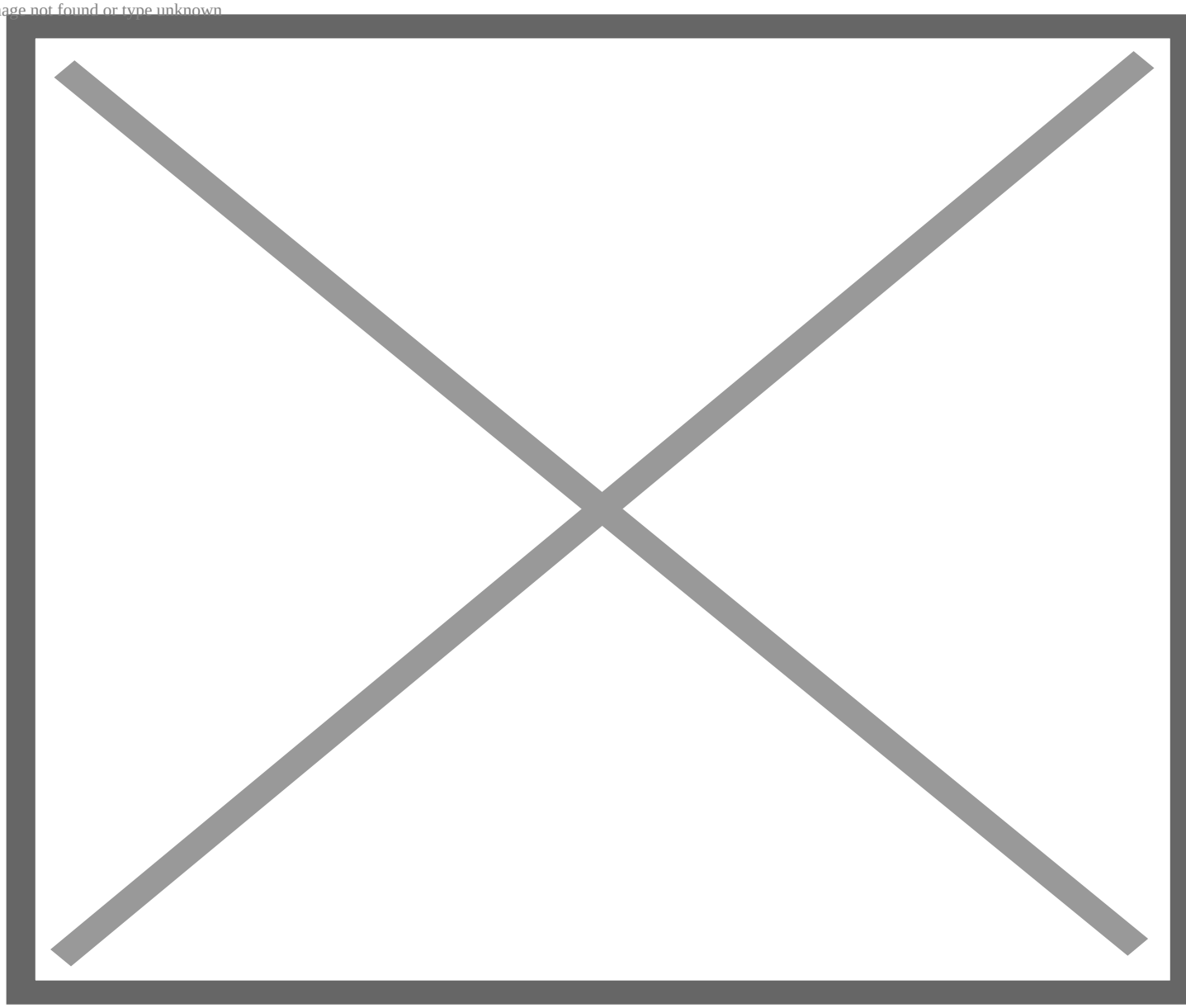
"I don't think there will be one model of agriculture in the future, but there is a push to move away from the industrial model of farming," says Hermione Dace, a policy analyst at the Tony Blair Institute for Global Change in London. "Traditional farming will still exist, but there will be less of it. Robotics will help traditional farmers apply inputs more precisely and reduce the environmental impact of farming as well as saving cost."

Nidhi Kalra, a senior information scientist at the Rand Corporation, a public policy think tank, says the current moment in agriculture recalls the Gartner Hype Cycle, a formulation of the adoption of new technology "which is basically that new tech comes in, dreams are vastly overinflated, those technologies crash and people say it's garbage, and then you come out of the valley and the tech starts doing useful things in the world."

If she's right, today's excited anticipation of agriculture's robotic utopia-to-come will inevitably give way to disillusionment as seemingly world-changing ideas amount to very little.

Kantor believes there have already been three or four robotic waves. In the 1950s, Walt Disney created Tomorrowland, the first really vivid demonstration of what very human robots might one day do. It generated a lot of excitement, but what came out of that period were industrial robots, bolted to factory floors and accomplishing a single rote task. Roughly every decade since then there's been some new technology that opened wider possibilities. He cites the personal computer, ATMs, and shopping kiosks.

Image not found or type unknown



Disney’s Tomorrowland has several nods to the “Agrifuture”. Credit: In Fine Taste

“Now we’re in a self-driving car wave and agriculture wave, and it’s going to recede,” he says. “I like to think of it as tides, waves washing up on the beach, and there’s a lot of excitement and then the waves recede, and one or two things are left behind and are useful.”

It ultimately will come down to what farmers choose. On his farm in Iowa, Slinker thinks of himself as pretty typical. He’s not on the cutting edge of technology, but he adopts what makes sense to him and what he has seen work for farmers he knows. But he will keep some things, too, even when it’s not completely rational.

And so, along with the modern equipment he uses to operate his farm, he holds onto an old tractor that belonged to his father. That tractor may not be part of the billion-dollar calculations being made on his behalf by people who spend more time in research labs and conference rooms than they do on the farm, but it should be. It's handy for hauling small loads without putting hours on his bigger, more expensive tractors. And it reminds Slinker, he says, of why he got into farming in the first place, and that's something he'd like to preserve.

Tom Johnson writes about technology, business, and whiskey in Louisville, Kentucky. He has written or co-written dozens of historical and military documentaries, and been published in Los Angeles, Newsday, Vineyard & Winery Management, Bourbon+, and other publications. Check out Tom Johnson's personal website at www.excellentproj.com

A version of this article was posted at Undark and is used here with permission. Check out Undark on Twitter @undarkmag