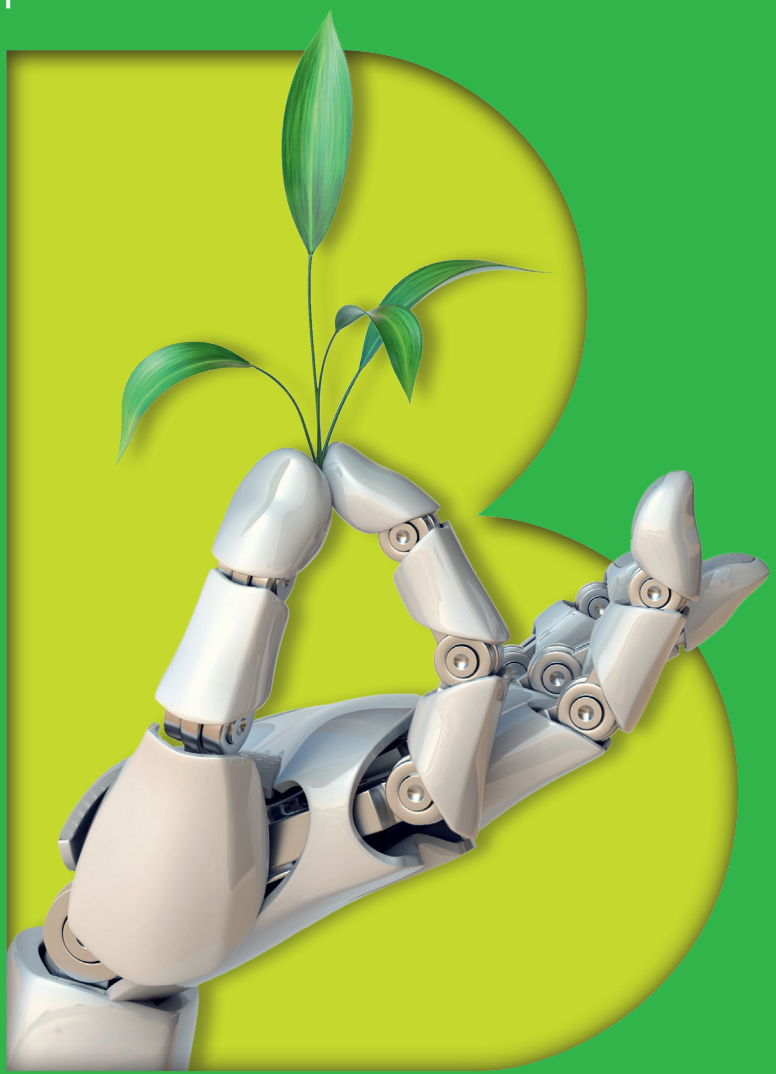
Roland Berger Focus

October 2019

Farming 4.0: How precision agriculture might save the world

Precision farming improves farmer livelihoods and ensures sustainable food production



Roland Berger

Management summary

Farming is under pressure due to global warming, falling commodity prices and high debt. Consumers demand ecological farming practices and sustainable food. How can industry respond and support farmers in this challenging situation? In this special report, we'll examine how crop protection companies, equipment manufacturers, and dozens of startups are engaging risk-averse farmers with sensors, biologicals, robotic automation, and digital data to improve farm yields and reduce input wastage. We'll also explore the role of collaboration in staying ahead on the innovation ladder and capturing a relevant piece of a rapidly growing precision agriculture pie.

Contents

1. Challenges in agriculture

An urgent need for change

Agriculture touches everyone's life like few other industries. Since food and water are basic necessities, farming is central to every nation's well-being. Whether the highly industrialized row crop farmers in the U.S. or Brazil, medium-sized cereal growers in Europe, or small subsistence farmers in India and China, our global economy relies upon all of these for basic food security. In that way, farming is vitally important, which explains its political clout and enduring influence, despite representing a small fraction of the total population in developed economies.

In today's environment, modern farming faces many challenges. Rather than covering an exhaustive list (consumer awareness, traceability, and bio-fuels to name a few), this report will concentrate on a few examples that highlight the need for change in the agricultural industry.

First and foremost, the agricultural sector needs to ensure sufficient food for a still growing global population. As per a recent UN report,[1] the 2017 global population of 7.6 billion is expected to grow to 8.6 billion by 2030 and 9.8 billion in 2050—an increase of 13% and 29%, respectively. Some 83 million people are born in the world each year, despite falling global fertility rates.

While the population continues to increase, the availability of arable land is decreasing. As per the Food and Agriculture Organization, soil destruction caused by chemical-heavy farming methods, deforestation, and global warming is proceeding at an alarming rate.[2] Since three centimeters of top soil take 1,000 years to develop, our current rate of replenishment is unsustainable. Given the rate of population growth, the amount of arable and productive land per person by 2050 would equal only a quarter of the total available land in 1960.

Doing more of the same is clearly not an option. As per a recent UN report,[3] land degradation will threaten the existence of about 3.2 billion people by 2050, cause species extinction (such as dramatically reduced populations of select insects and birds in Europe), intensify climate change, and lead to mass migrations. While human migration pressure has made headlines recently, the migrations from epic environmental destruction will inevitably lead to violence.

Farmers, as the original custodians of the land, understand these challenges well. In the midst of all this upheaval, however, farmers are getting older. They are finding it increasingly difficult to find and keep labor to support them in the field. They are often under financial pressure. → A When coupled with their traditional risk-averse nature, this makes it especially difficult for them to invest in unproven technologies.

Agriculture, and with it the world, clearly has a burning problem. Change is needed. If industry participants do not react in time to these challenges, they will face increased activist pressure and regulatory action, similar to the emission regulations that were previously imposed on the automotive industry.

Of course, there is no silver bullet to address the challenges we face. No magic wand we can wave to ensure everyone has bountiful, nourishing food on the table. In fact, solving today's challenges will require the application of many levers.

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[1] World Population Prospects: The 2017 Revision, https://www.un.org/development/desa/publications/world-population-prospects-the-2017-Revision, accessed on February 9, 2019

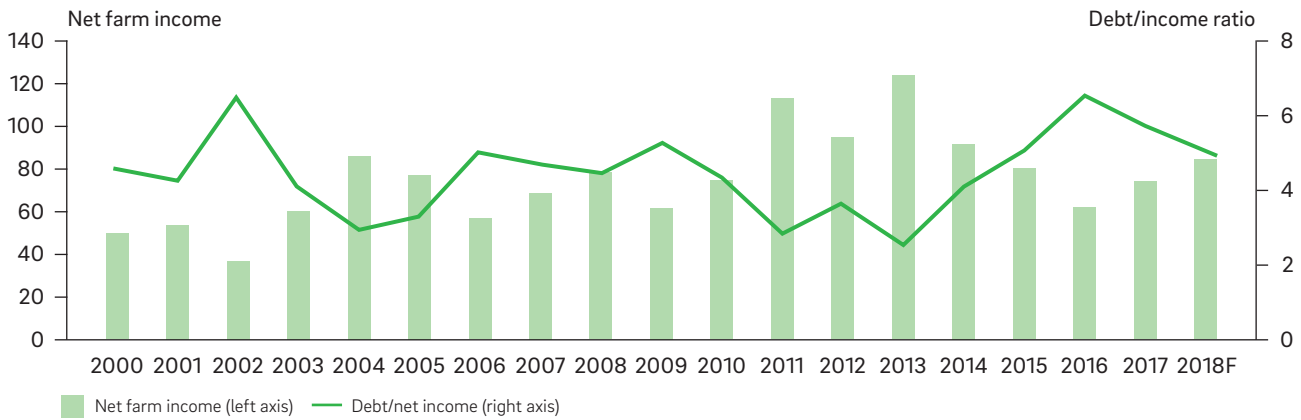
[2] Arsenault, C.: Only 60 Years of Farming Left If Soil Degradation Continues, Scientific American – https ://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/, accessed on February 9, 2019

[3] Willemen, L. (ed.): Summary for policymakers of the thematic assessment report on land degradation and restoration. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bonn 2018, p. 3

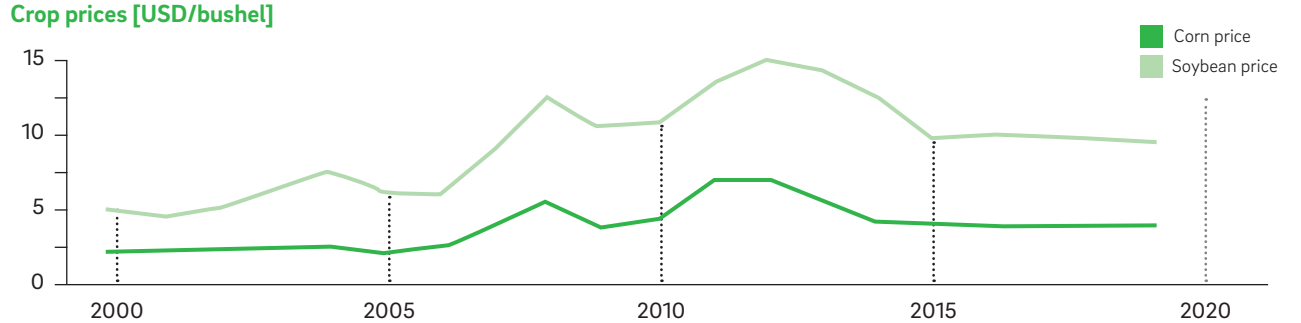
A: U.S. farmers are increasingly feeling the pressure of falling crop prices and incomes coupled with a dramatic increase in debt

Economic environment for farmers

United States net farm income [USD bn] and debt/net income ratio



Crop prices [USD/bushel]



Comment

As farmers continue to face economic pressure, investment in and adoption of new technologies is slow	High level of debt and increasing interest rates weigh on farmers' livelihoods	So far, land prices seem to be holding but first rumors about declining prices can be heard	Trade war with China likely to lead to permanent market share loss for American soy farmers similar to results of Carter's wheat boycott against Russia in the 1980's

Farmers are generally risk-averse and need to be convinced of a clear return on investment in order to adopt new technologies

Source: USDA, Roland Berger

Feeding the world in a sustainable manner and convincing farmers that this works is the key challenge of precision farming.

Reducing food waste is paramount. Yearly, about 1.3 billion tons of food produced for human consumption are wasted throughout the supply chain.[4] With total global food production of 3.9 billion tons, this amounts to about 30% annually. Besides optimizing the supply chain, consumers must change the way they consume food, especially in developed markets. According to a recent report by the Commission for Environmental Cooperation in Montreal,[5] about half of the food waste in the U.S. and Canada is caused by consumers at the tail end of the supply chain.

Not only must we reduce food waste, we must shift food consumption towards a more vegetarian diet. As per a recent study by the University of Oxford, meat, aquaculture, eggs, and dairy use about 83% of the world's farmland and contribute 56–58% of food emissions. Yet only 37% of our protein and 18% of our calories stem from these food sources. Shifting the planet to a vegan diet would reduce food land use by 76%, greenhouse gas emissions by 49%, acidification by 50%, and freshwater withdrawals by 19% from 2010 levels. What's more, consuming more produce has measurably resulted in better health, so the case for a more plant-based diet could not be clearer.

Beyond these two big opportunities, how we operate farms today is another area ripe for change. For one, farming practices within the same crop type, land size, and geography vary immensely, which creates several opportunities for further optimization. Across geographies, these differences are even starker. Take, for example, average fertilizer use. The average value for this ranges between 1 kilogram of nitrogen per hectare in Uganda to 300 kilograms of nitrogen per hectare in China.[7]

Last, but definitely not least, precision agriculture holds the promise of significantly improved yields, even while reducing input costs. Improvements in both hardware and software technology are opening a new chapter in agriculture, especially in the case of sensors, biologicals, robotic automation, and digital data. Rather than being a domain for conservatism, agriculture today is at the forefront of the Internet of Things (IoT) revolution.

[4] Global food losses and food waste – Extent, causes and prevention. Food and Agriculture Organization of the United Nations – http://www.fao.org/3/a-i2697e.pdf, accessed on February 11, 2019

[5] Characterization and Management of Food Loss and Waste in North America. Commission for Environmental Cooperation (CEC), Montreal, 2017, p. 48

[6] Poore, J. and Nemecek, T.: Reducing food's environmental impacts through producers and consumers. Science Vol. 360, Issue 6392, 2018, pp. 987–992

[7] ibid.

2. Precision agriculture is the future of farming

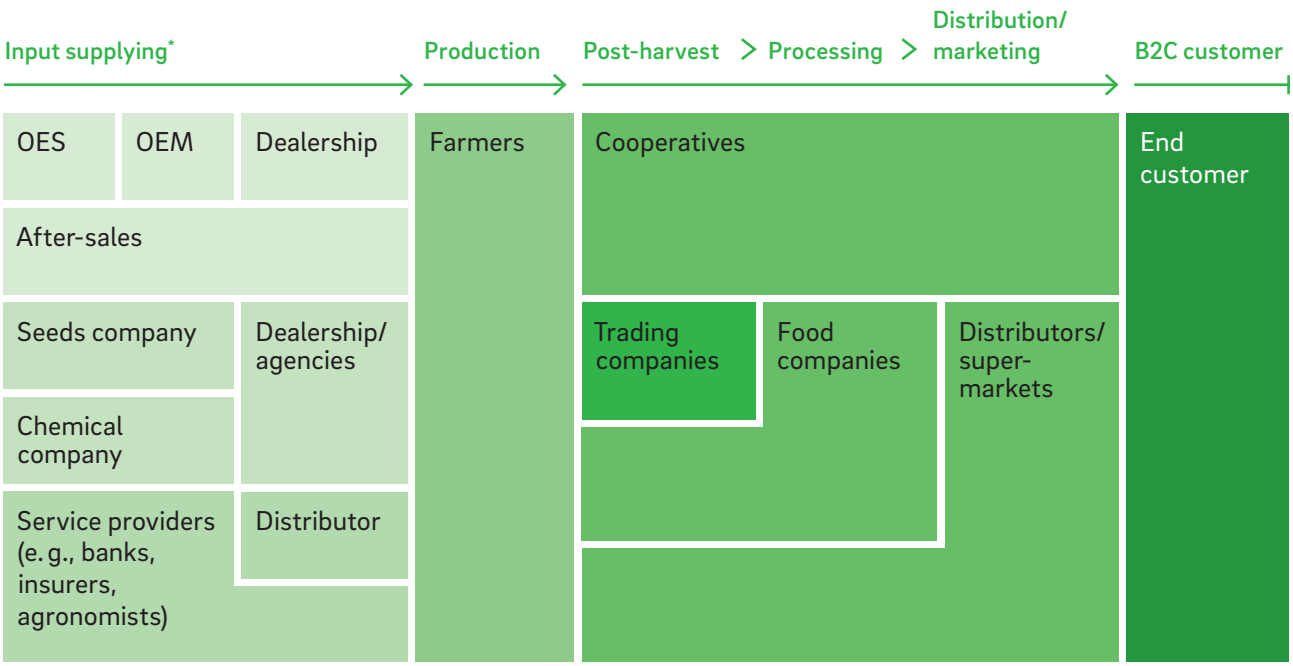
Doing more with less by leveraging technology

When looking at the aforementioned challenges, it is evident that all of the solutions mentioned need to be pursued in unison. Our focus here is on precision farming, which we believe to be essential for the future of all participants in the agricultural value chain. → B

Technology solutions include a vast range of applications such as the management of fleets, drones and data, farm management (soil, seed, crop health and pest monitoring), prescriptive seeding and spraying, implement and row guidance systems, vertical farming, and hydro-/aeroponics. In this report, we will provide a general overview of some of the most promising technologies being adopted and used by agro-chemical companies, original equipment manufacturers, suppliers, technology providers, and select startups. We will highlight the major opportunities and challenges that participants face and speculate on potential implications of these new technologies. ›› See interview on page 8

B: Precision farming technologies impact the entire agricultural value chain from the input supply to the end customer

Agricultural value chain



* Including machinery/spare parts, seeds, herbicides, advisory/prescription services, etc.

Source: Roland Berger

After extensive research, we've identified four primary technologies that define precision agriculture and ultimately the future of farming. They are imagery & sensors, robotics & automation, digitalization & big data, as well as biologicals. → C Three of these technologies work closely together, namely sensors, robotic automation, and digital data, and are enabled by adequate connectivity as well as the improvements in edge computing and the cloud.

Additionally, precision agriculture has progressed with the help of other technological trends. For one, hardware costs have come down dramatically in recent years. For instance, an automotive lidar sensor that is used for autonomous driving solutions was USD 75,000 at the beginning of the decade and was about USD 7,000 in 2017, a 90% reduction in only a few years.[8] Similarly, computing power has continued to follow Moore's law on average over the last decade.[9] While the exponential growth may only continue for a few more years, computing power today is already at a level that enables advanced technologies.[10]

This increase in computing power will only expedite machine learning and artificial intelligence applications. The good news is that machine learning and artificial intelligence have already proven themselves with many

›› Interview

DAVID BENELL

Manager – Food, Land and Water, World Business Council for Sustainable Development

Understanding the voice of the farmer and co-creation are key

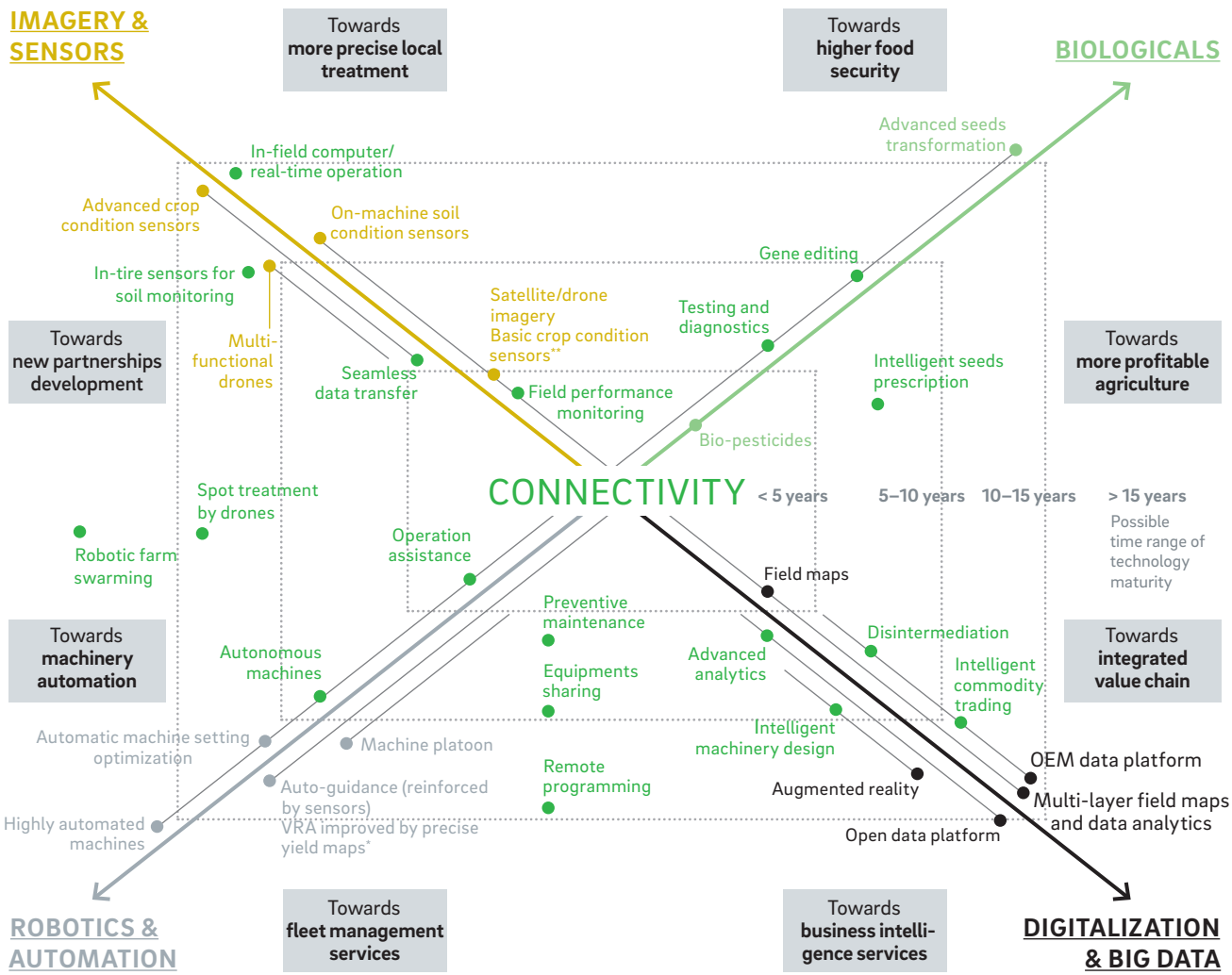
Precision farming is the future, there is no chance to put this genie back in the bottle. Feeding 10 billion people in a healthy manner cannot be done with existing farming techniques. However, agricultural OEMs, agro-chemical companies, technology players, startups, universities – everybody is facing the same question: Which horse should we bet on? Looking at rapidly changing technologies, this fast development is a key critical uncertainty that will keep many managers in these companies awake at night.

Another key challenge is to truly understand the voice of the farmer. Looking at lead users among various farm types and understanding how to create value and how to communicate this value to customers is a task that some companies have difficulties with. In-depth understanding of a good cohort of farmers, in my opinion, will lead to better results than millions of data points.

Co-creation is another point that is crucial here. The mountain bike, the snowboard, Gatorade, roller blades, etc. were all invented by people who were trying to solve real world problems that they faced. Working with farmers, understanding their challenges, and then turning this into insights regarding products and services holds the key and will differentiate successful from less successful companies.

I strongly believe that we can't impose technological solutions on farmers, but the solutions that we come up with have to be farmer and people centric. Business models need to be win-win.

C: Players leverage four major technology levers to drive improvements in the farm economy and shape a new agriculture ecosystem
Agriculture industry technology map



Source: Desk research, expert interviews, Roland Berger

early successes, such as AlphaGo's victory over the world's leading Go player, the discovery of an eight-planet solar system based on Kepler data, and self-programming and self-taught chat bots. While some advances in AI are controversial, their potential opportunity for the welfare of humans is undeniable. Together with edge computing and the cloud, as well as increasingly better connectivity for large farms, the basic building blocks for a revolution in farming are already in place.

That being the case, the global precision agriculture market is projected to grow at very healthy rates. From a current base of USD 3.4 billion in 2017, the market is expected to grow at 12.8% CAGR to reach USD 5.5 billion by 2021.[11] So far, EMEA has been the dominant market, with 41% market share as of 2016, followed by APAC (32%) and the Americas (27%). In the near term, the growth momentum in all three regions is rather similar, hence market shares are unlikely to change significantly by 2021.

The size of the prize is substantial and drives significant interest and investment in the sector. Overall, in 2017 alone, roughly USD 4.2 billion flowed into the agrifood tech space according to AgFunder.[12] Take Bayer (which now includes Monsanto) as an example. → D The company has set up a team of more than 400 professionals and invested about USD 1.25 billion to drive the development of digital offerings for farmers. Proprietary models that deliver insights and recommendations for Bayer's customers are the most notable focus. On the startup and venture capital side, investment has grown aggressively as well. Finistere Ventures puts the value of VC deals in the agtech space at roughly USD 1.3 billion as of 2017,[13] with both the number of deals and overall transaction values strongly growing over the last half decade. Either way, the commitment to and excitement surrounding precision agriculture is palpable.

While individual approaches and solutions differ due to farm size, crop type, geography, and farming methods, all players are attempting to create optimized value for farmers. Generally speaking, finding an adequate solution that is acceptable to farmers can be difficult. Across farm types, farmers cite difficulty when using precision agriculture methods centered around connectivity, the lack of integrated platforms, the lack of predictive advice, and insufficient information about the proposed precision agriculture solutions. → E We believe these challenges can be overcome, however, especially with stronger collaboration. ›› See interview on page 9, 13

[8] Introducing Waymo's suite of custom-built, self-driving hardware. Waymo – https://medium.com/waymo/introducing-waymos-suite-of-custom-built-self-driving-hardware-c47d1714563, accessed on February 12, 2019

[9] Intel – https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/03/Kaizad-Mistry-2017-Manufacturing.pdf, accessed February 13, 2019

[10] ibid.

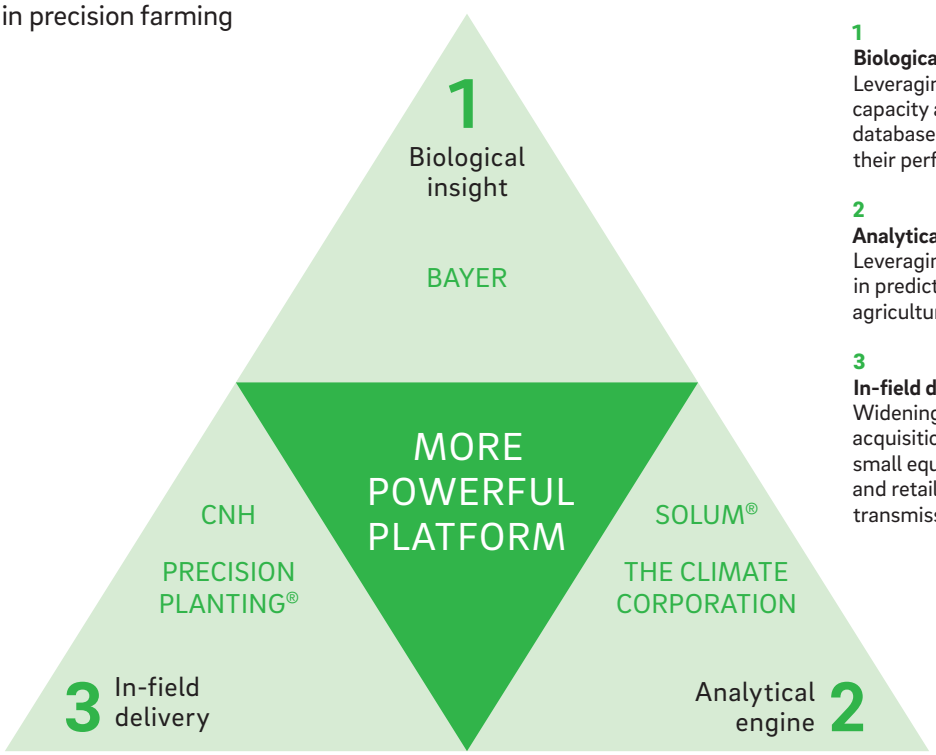
[11] Global Smart Farming Market 2017–2021, technavio.com, 2017

[12] Upstream investments only – https://research.agfunder.com/2017/AgFunder-Agrifood-Tech-Investing-Report-2017.pdf, accessed on February 9, 2019

[13] 2018 Agtech Investment Review, Finistere Ventures LLC – https://files.pitchbook.com/website/files/pdf/Finistere_Ventures_2018_Agtech_Investment_Review_PJZ.pdf, accessed on February 9, 2019

D: Bayer has taken steps to develop its presence in the precision farming space with substantial investments

Bayer strategy in precision farming



1
Biological insight
Leveraging Bayer's R&D capacity and massive database on genetics and their performance

2
Analytical engine
Leveraging deep experience in predictive analytics in agriculture

3
In-field delivery
Widening partnership or acquisitions with large/ small equipment providers and retailers, allowing data transmission to the field

Brief market entry strategy
Originally an agrochemical and agricultural biotechnology company
Entered the precision farming market by acquiring several players to **extend the value proposal**
Developed **"Integrated Farming System"** allowing farmers to maximize yield productivity

Year	Company	Specialty
2012	PRECISION PLANTING®	Producer of hardware and software for accurate planting
2013	THE CLIMATE CORPORATION	Data provider for weather forecast/insurance
2014	SOLUM®	Soil measurement laboratory and software solution provider

BASF, Corteva and Syngenta are all expending significant resources in an attempt to catch up to Bayer in digital/precision farming

Source: Roland Berger

E: Large-scale farmers in the agribusiness model tend to face difficulties in properly implementing and using data

Farmer pain points by business model

BRAZIL

8,500 ha

Sugar cane
Soy
Corn
Wheat

Digital technologies used

Automated steering following field edges

GPS field mapping

Weather & soil monitoring

Pain points

Limited broadband coverage for high quality data transmission

Incompatibility of offered digital tool set

No synthesis of all data inputs on a common platform

1 Industrial agribusiness model

FRANCE

125 ha

Sugar beet
Cereals
Soy
Oil seeds

Digital technologies used

Automated steering following field edges

GPS field and soil mapping

Pest/disease identification

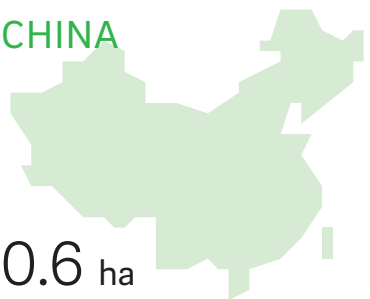
Pain points

Lack of transparency & knowledge on application timing & rate of crop protection chemicals

No transparency on where products are coming from

2 Crop specialist model

CHINA



0.6 ha

Cabbage
Strawberries
Peppers
and others

Digital technologies used

Growth stage monitoring via camera

Shared agricultural machinery via online platform

Pain points

Lack of transparency regarding information on new products offered by different distributors

Time consuming ordering process

3 Regional crop protection model

Source: Roland Berger

›› Interview

JAMES MILLER

Group CTO, Tafe – Tractors and Farm Equipment Ltd.

Addressing challenges and leveraging opportunities in emerging markets

From an Indian perspective, our challenges in farming are all focused around reducing upfront costs, waste reduction through better storage and distribution, as well as bringing up the yield per hectare. In many crops, we are still at 50% or less in terms of tons per hectare vs. global benchmarks. Part of this would require land consolidation, a lot of it requires improving farming practices. As a consequence, leading edge precision farming technologies such as single seed planting, care and nurturing are still a long way off. With low mechanization – tractor penetration is only around 20 per 1,000 ha on average and less than half of all of India's farmers have access to a tractor – driving mechanization is the first priority and an obvious area for yield improvement.

A possibility to address some of these challenges is via farmer rental apps, such as TAFE's JFarm Services app. You can think of it as an Uber for tractors and equipment. Farmers and Custom Hiring Centers (CHCs) with tractors and equipment can make them available to farmers who need them, leveraging the asset more efficiently and driving up productivity for other farmers.

Also, as about 80% of farms are less than one hectare, precision farming for these farms will have to be fundamentally different from solutions that are developed in the West. Developments for these segments will have to be extremely cost competitive and we will need to take a longer term view in terms of tapping these segments. The remaining 20% are larger farms which are the first to adopt precision farming practices. Applications for these lead farms will have to be scaled down for lower horsepower and smaller equipment requirements vs. Western solutions.

Practical solutions will be critical. Farming labor on a short term basis in India is scarce and there is an increasing reluctance to carry out manual labor when there are better paid jobs in urban areas. Due to the manual effort that currently goes into farming, mechanised solutions can create real value for farmers. We need to be able to develop automated solutions for equipment that is at least as accurate as the manual equivalent.

App-based advice, be it the prices in various mandis or agronomist advice, is an area that is promising as well. Here we believe that the knowledge sharing and education provided by our JFarm adaptive agri-research center is an asset. We have been advising farmers in the past on pest control, right crop selection, right fertilizer application, land management, etc. and can now bring this value to farmers more effectively. These initiatives are key to demonstrate value to farmers. Unless farmers can see with their own eyes that whatever you do has real positive impact in terms of field economics, they are unlikely to adopt new practices.

Startups are very active in India. The young generation is jumping on solutions for farmers across the country looking at drones and imagery, pickers, pluckers, cutters, etc. that are simple to operate. Other areas are weather mapping and farm management solutions. Global technology companies find the going tough in the Indian environment. They often have challenges translating global solutions into the extremely cost sensitive Indian environment. This is where local startups are coming to the fore by connecting with the farmers and developing solutions that are affordable and that work.

OEMs are playing the role of integrators. As technology moves very quickly, it makes little sense to re-invent the wheel. At TAFE, our focus is to drive down costs for farmers and increase their productivity and yield, not to become a software company. A small percentage yield increase may allow farmers to re-dedicate portions of their land and plant higher value crops. These kind of approaches will be necessary to double farm incomes by 2020, a stated objective of the current government, and an essential step towards providing the funds for farms to adopt precision agriculture technology.

3. Knowing the main protagonists

Finding your way in a rapidly developing environment

Precision agriculture is a crowded field. The opportunity to have a hand in sustainably feeding the world and earn a return while doing it is highly motivating for agricultural equipment manufacturers, agro-chemical companies, suppliers, technology providers, startups, venture capitalists, banks, and universities. Consequently, farmers and participants in the field are faced with rapidly changing technology and a provider landscape that is globally dispersed. → F The U.S. with its robust startup ecosystem is the world leader in agtech investments with over USD 1.8 bn total spend in 2016, followed by China (USD 480 m), India (USD 350 m) and Canada (USD 150 m). Innovation is not limited to highly populous countries though – Israel, well known as a hub for startups, has even outspent the U.S. in agtech investments on a per capita basis.[14]

Technological development happens at a rapid pace across the globe. Companies need to ensure they are integrated in relevant ecosystems and take a portfolio approach for their development road maps.

Picking the winner or winning solution in such a dynamic environment is difficult, if not impossible. There are, however, clear leaders in precision agriculture that are setting the pace. → G → H

For their part, tractor and implement manufacturers realize that novel technologies such as swarm operations or innovative crop protection technologies inherently hold the potential to disrupt their industry and business model. The current focus of global OEMs centers around fleet management solutions to improve the productivity of equipment through services such as machine health monitoring and preventive maintenance. Large OEMs are entering the farm management space through soil mapping, yield mapping, pest and weed detection, and precision technology. Various imaging technologies have been adopted with different levels of maturity. At the moment, autonomous technology is being pursued by only a few large OEMs.

For example, John Deere boasts a large number of connected, big data solutions that include fleet management (JDLink, AgLogic), drone data management (Sentera), yield mapping (Greenstar 3), soil monitoring (JD Field Connect), seed monitoring (SeedStar Mobile), and yield quality monitoring (HarvestLab). Among others, automated farming solutions include auto guidance vehicles, row guidance, implement guidance, variable rate technology (VRT), and boom height control. As you can see, investment in these technologies over the last 10 years has paid off. ›› See interview on page 21

Kubota is another manufacturer that has significantly invested in precision agriculture. Driven by a contracting and aging Japanese population, especially

[14] Austalian AgTech: Opportunities and challenges seen from a US venture capital perspective – https://www.ussc.edu.au/analysis/australian-agtech-opportunities-and-challenges-as-seen-from-a-us-venture-capital-perspective, accessed on February 15, 2019

G: OEMs and tech players focus on data-driven business models; startups concentrate on soil/crop monitoring

Technology heat map for key market participants

Source: Expert interviews, secondary research, Roland Berger

H: Crop protection companies have also made significant investments in technology to secure sustained success at the farm level

Customer services and selected digital offerings*

Type of Service	Customer Services	BAYER	BASF	CORTEVA		SYNGENTA	FMC
BASIC ADVISORY SERVICE	Information material	●	●	●	●	●	●
	Education/training	◔	●	◕	◕	●	●
	E-marketplace	◕	○	◔	○	○	○
	Electronic business	●	○	○	○	●	●
	Plant advice/diagnosis	●	●	●	◕	◔	◔
	Fleet management	○	○	○	○	○	○
	Financing/insurance	◔	○	○	○	○	○
ADVANCED DATA GATHERING (HARDWARE)	Weather tracking	●	●	●	●	●	○
	Soil monitoring devices	●	○	○	●	●	○
	Integration communication	●	●	●	◕	◕	○
	Remote sensing tech.	●	○	○	●	○	○
	Satellite/drone mapping	●	◕	◕	●	◕	○
ADVANCED DATA ANALYTICS (SOFTWARE)	Data library/storage	◕	◕	○	◕	◕	○
	Weather monitoring	●	●	●	●	●	●
	Soil monitoring	●	○	◕	◔	◔	○
	Real-time advice & diagnosis	●	●	●	◕	◕	○
	Yield data	●	●	●	◕	◕	○
APPLICATION SERVICES (SOFTWARE)	Precision position. system	●	●	○	◕	○	○
	Automated steering system	●	●	◔	◔	◔	○
	Variable rate application	●	◕	◔	◕	◔	○
Global focus		North America	Europe	South America	North America	North America	North America
Seeds vs. chemicals focus		Seeds & Chemicals	Selective Seeds & Chemicals	Chemicals	Seeds & Chemicals	Seeds & Chemicals	Chemicals

Source: Roland Berger ● Full service offering ○ No service offering * Company information

in the farm segment, the company has a strong focus on automation and autonomy. For example, Kubota is currently focused on relatively smaller tractors (60 HP) which can operate in a swarm, reducing the need for tractor operators. Other innovations, such as the "Raku Vest" (a mechanical arm support that is used, e.g., for grape farming) are technologies that relieve the stress of farm work.

Automotive suppliers are interested in precision agriculture as well. Bosch, for example, partners with start-ups to develop sensor-based solutions for agriculture and differentiates itself with its capabilities around hardware and software integration. Current applications include sensor technology to track soil moisture and weather, disease prediction systems for greenhouse applications, wireless tree sensors to determine optimal irrigation plans, and autonomous farm robots ("Bonirob") for weed management. Bosch also collaborates with Bayer to develop smart spraying solutions for sustainable weed control.

Similarly, agro-chemical suppliers such as Bayer have invested heavily in precision agriculture. → D Adding to its existing biological edge, Bayer has acquired the following companies: Precision Planting (hardware/software for accurate planting), The Climate Corporation (data for weather forecasting/insurance), and Solum (software-based soil measurements). In turn, BASF, Corteva, Syngenta and FMC are all expending significant resources to catch up with Bayer's early lead in precision agriculture.

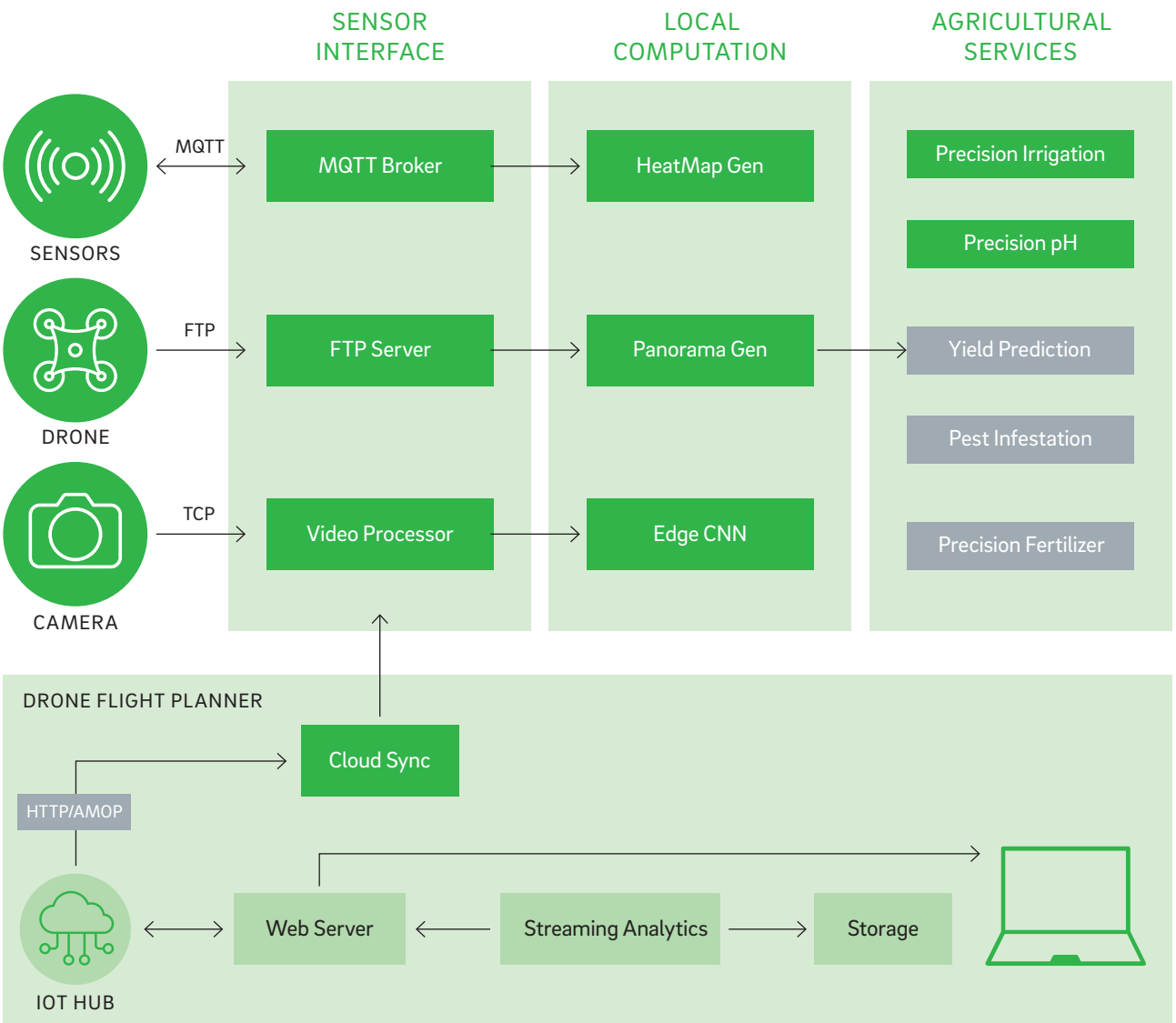
Besides large investments, the impact of crop protection companies is important from a business model perspective. As their primary objective is to sell seeds and chemicals on a repeated basis to farmers, data and model-based insights are often used as loss-leaders in the sales process. Independent data or analysis providers (incumbent or startup) will therefore likely encounter resistance to stand-alone prices and margins.

Precision agriculture solutions require integrated, scalable platforms that are leveraged across products and industries.

Players outside the industry will come up with new solutions and challenge incumbents.

Technology companies such as Trimble and Topcon are focusing on bringing "full service" solutions to market. Based on significant scale across various industries, these companies provide complete hardware and software packages for autonomous solutions, precision agriculture, and overall farm management. As service organizations, they understand outcome-based business models potentially more intuitively than either agro-chemical companies or agricultural equipment players. Understandably, this is an important advantage in a rapidly changing precision agriculture environment. Taking their success in other industries (e.g., commercial vehicle telematics) as an indication, these companies will likely play a central role in shaping the future of precision agriculture.

I: Microsoft leverages the Azure platform to build an open ecosystem in agriculture, FarmBeats
Overview of FarmBeats architecture



Source: Microsoft, Roland Berger

Unsurprisingly, technology heavyweights such as IBM, Amazon, and Microsoft are also taking precision agriculture seriously. For instance, Microsoft has recently released a beta platform called "FarmBeats" that intends to be the "underlying plumbing" of the precision agriculture world. → I FarmBeats solves the farm connectivity problem by using TV white spaces (the frequency of unused TV channels) to connect the farm to the cloud.

Based on the Azure platform, FarmBeats offers a ready to use set of algorithms, including sensor fusion, machine learning, and edge computing that can be easily accessed by application developers via API (application programming interface). What's more, Microsoft is building a data repository of publicly available data and provides this data to members in its open ecosystem. Member data remains the property of the application developer or farmer. Understandably, this innovative approach resonates well in the precision agriculture community.

On the small but fast growing side, startups focus on on specific offerings in the alternate farming space and differentiate themselves with impressive data processing, algorithms, and AI capabilities. A number of startups are actively trying to disrupt established patterns and business models. Indigo, for example, is headquartered in Boston's biotech hotbed and has developed a microbes-based technology that improves crop drought and disease resistance, as well as reducing the need for fertilizers. → J To minimize the risk to farmers and facilitate the adoption of their technology, Indigo gets paid a percentage of the incremental yield[15] that their solution has generated for a farmer. Such outcome-based models are attractive to farmers and could well point the way to the future. As evidence of their quick success, Indigo has grown from 150 to 500+ employees in just 18 months.

The industry will move to outcome-based models and undergo a major disruption. Companies need to preserve their existing business while simultaneously preparing for the future.

[15] Increased yield of treated vs. yield of non-treated acres

J: Startups like Indigo use digital technologies to change value propositions and create innovative value capture business models
Digital case study

TECHNOLOGY

Microbes are **utilized** to improve plant performance:
- Draught resistance
- Disease resistance
- Reduction in need for nutrients and fertilizers

Combination of **agronomy** and digital **technology**

Big data applications and analytics are used to identify specific and individual needs to benefit farmers

Novel biological technologies to **reduce** the **need** for **nutrients** and **fertilizers**

Fleet of drones and extensive use of satellite imaging to determine yield of treated vs. non-treated acres in same climate and soil conditions

VALUE TO FARMERS

Risk reduction – Farmer only pays a percentage of the incremental revenue increase (the increased yield vs. yield of non-treated acres)

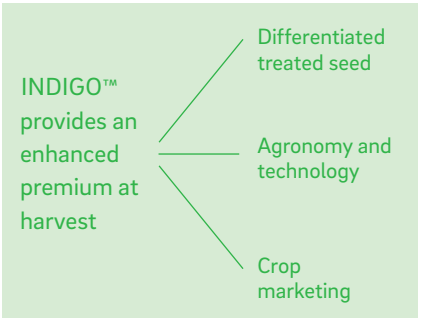
Improve yields and **reduce the use** of **fertilizers**

Reduce the need for **nutrients**

Lower costs for general agricultural supply

Lower risk for crop diseases

Tailor-made differentiated seed solutions for individual agricultural demand



BUSINESS

Initial focus on cotton seed treatment to improve yield in dry conditions

Expanding globally, initial target markets are U.S., Brazil, and Australia

Have **grown from ~150 to 500+ employees** in last 18 months

Three services being developed:
- Output-based seed
- Microbiome seed treating and microbiome effectiveness testing (field testing and data management) for agricultural startups
- Crop value maximization linking farmers' specific crops to higher value buyers, directly displacing traders/ silage providers

Total cash raised USD 600+ m

Source: Company information, Roland Berger

›› **Interview**

DR. JOHN F. REID, JD FELLOW

Director, Product Technology & Innovation, National Academy of Engineering, Deere & Company

Taking disruption head-on

The world around precision farming is truly exciting. Major players such as John Deere are moving from their traditional area of comfort – products and equipment – to a more digital future, driven by data, information and the relevant insights that can be derived. Farmers as customers have lots of ecosystems to choose from. The excitement around these new technologies drives incumbents and new entrants – be it technology players such as Amazon, Google, and Microsoft or startups – to invest heavily in the space and to constantly advance the art of the possible.

One key trend in all of this will be the requirement to integrate equipment across various brands. As solutions and options proliferate, outcome-based approaches will gain in relevance and the traditional brand loyalties, e.g., in the US market, will weaken. Hence, companies that traditionally were fierce competitors will have to find ways to cooperate. We will see a trend towards open systems that allow for interoperability. Fully closed systems are likely to be too slow as far as adapting to changing environments and technologies is concerned. As such, the DNA of incumbents, who are used to competing based on what they do and not based on being a systems integrator, will have to change.

The agricultural market will be changed by new entrants. Companies that understand little of agriculture but see it as a way to leverage scale from applications in other industries will look at the challenges of farmers with fresh eyes and will come up with new solutions. Take Airbus (who recently received an innovation award at the Agricultural Exposition Sima in France) as an example. Here you have a company that has decided to enter the agricultural space and provide imagery solutions. Something that would have been thought of as unlikely, unusual just a few years ago.

Machinery will continue to be fundamental in terms of its relevance for delivering the work outcome of farming, but, with the advent of digital technologies, its character will change from being a differentiated product to a mechanism to drive farm outcomes. This will change the farming ecosystem completely.

At the same time, you have to stay abreast of technology. I learned in the past that it helps to look back 20 years and try to look forward 20 years. In the late 1990s, we did not have cell phones, the cloud, internet business models, etc. And electrification looked like it had failed at its first attempt. Today, these technologies are at the center of our lives. Similarly, blockchain, AI, 5G and other technologies are likely to be the mainstay of farming technology 20 years from now, and will enable farm operations to be more integrated and easier.

Ecosystems will drive a lot of this change. When I developed autonomous vehicles 15 years ago, I had to develop my own devices to get this done. When I worked on it 10 years ago, I had to develop my own infrastructure. Today, devices, infrastructure and other enabling technologies are more accessible and you have several options to choose from. Twenty years from now they will be even more available and empower an automated and connected approach to digital agriculture.

In this world, incumbents cannot be myopic and assume that they own the space; we need to be ready for huge disruptions. Ever expanding digital technologies will have the ability to help farmers at all scales, large and small. Farmers are innovators at the core, and data and data analysis will enable them to further professionalize their business.

4. Managing the transition

Addressing opportunities in an extended ecosystem

As mentioned earlier, farmers experience significant challenges when trying to adopt sensors, biologicals, robotic automation, and digital data from third party providers. The right product mix varies widely across farm size, crop type, geography, and farming practices. Farmers are traditionally conservative and will only adopt new technology because of its utility, rather than just the technological appeal. Consequently, compelling applications must be significantly deep to deal with the specific situation of the farmer but also based on integrated solutions that make handling data and insights easy and seamless.

Increasingly, technology investments will require global scale as well as scale across applications in several industries as the Microsoft example has shown. Agility in adapting solutions to specific use cases will remain a differentiating factor, as will respect for data ownership and the entrepreneurial independence of farmers.

Other participants in precision agriculture such as lenders and insurers are logically interested in risk mitigation and outcome-based business models. For example, in asset-light farming, crop-based lending can play a major role for farmers. Such a lending approach depends significantly on predictive models to reduce risk and price loans adequately. Understanding and fulfilling these requirements is an opportunity for precision agriculture. But it's unclear which player in the ecosystem will be best positioned to serve these needs.

›› See interview on page 24

For traditional agricultural players, this transition is not easy. As the industry moves from products to outcome-based solutions and worksite optimization, many organizations face the conflict of traditional platform or product-based organizations versus the needs of the farmer and marketplace. While the traditional business model still pays the bills, and will likely do so for some time, developing and nurturing an alternative approach with corresponding incentives and culture is challenging.

These challenges are not unique to the agricultural industry. In the automotive industry, autonomous and electric vehicles as well as shared mobility are already rewriting the rules of the market. Manufacturers in this field must also identify how they can preserve their "OEM 1.0" business model for as long as possible, while simultaneously developing an "OEM 2.0" model for the future. Defining the right organizational model for this transition is challenging to say the least. But the transition is feasible, especially when considering promising examples such as Michelin's Tire-as-a-Service or Rolls-Royce's Power-by-the-Hour business models.

Similarly, crucial questions center around make vs. buy decisions. For most OEMs and agro-chemical players, owning all technologies and related capabilities and responding to market changes as quickly as technology providers or startups will prove elusive. Hence, a critical look at what capabilities are core in the future is required.

Asset-light farming is a growing trend and can be served well via outcome/crop-based lending. The focus here is on providing funds to improve farming practices.

K: In the automotive industry major players are engaging in intensified startup activity including corporate venture capital, accelerators, and incubators
Industry examples

	Independent CVC	Accelerator	Incubator	Others
BOSCH	Robert Bosch Venture Capital (3 funds to date)	DNA accelerator program M.TECH Accelerator (Stuttgart)	Robert Bosch Startup GmbH	Bosch Venture Forum Chicago Connectory Startup Harbour Berlin
BMW	BMW iVentures	Lab accelerator program Financial Services' Collaboration Lab accelerator program Partnership with Urban-X	Startup Garage at BMW	Customer to startup Joint mobility company (Berlin) Startup competition at StartupFest Europe 2017
VOLVO GROUP		Volvo Financial Services' Volvo Financial Services' iLabX	DRIVE	Volvo Group's CampX MobilityXlab Campus Lundby
DAIMLER	Daimler Group Venture Capital	Lab1886 Startup Autobahn Partnership		Startup Intelligence Center FC think! tank Startup Intelligence Center DigitalLife@Daimler
CONTINENTAL	Continental Corporate Venture Capital		Continental Incubator	Continental Startup Cooperation Program

Corporate Venture Capital (CVC)
A subset of venture capital wherein corporations make systematic investments in startups tangentially related to the company's own industry, often by taking an equity stake

Accelerator
Startup accelerators support external companies through education, mentorship, and financing

Startups enter accelerators for a fixed-period of time, and as part of a cohort of companies

Incubator
Incubators support companies or single entrepreneurs (often own employees) in the early stages of development and do not operate to a set schedule

Source: Roland Berger

Established companies need to find effective ways to engage with broader ecosystems to leverage market developments. Technology challenges hence take on the character of portfolio decisions. Management will have to decide which technologies to divest and in which areas to bring capability in-house (e.g., via acquisitions, joint ventures, or collaborations). Again, the automotive industry can serve as a guide, as leading companies have built up a solid engagement model with the broader mobility ecosystem. → K

›› Interview

DARWIN MELNYK

Co-Founder, CTO and Business Development, FarmOp Capital

Enabling asset-light farming with innovative lending approaches

Acceptance of precision farming solutions for broad acre row crops, for example, in the U.S., is challenging. We have about 90 m acres of corn and 60 m acres of soy. Whatever solutions are proposed, they need to be able to scale and ensure that they provide a decent payback for large farms with crops that have generally low margins. Anything that has an ROI of 5+ years is a really tough sell. Even if we take basic investments such as tiling for drainage, we often see that farmers are not investing in this due to the relatively high cost per acre. Big producers often think year-to-year, they don't see things on a 5–10 year time horizon.

Also, we see the trend towards asset-light tenancy farmers continuing. The consolidation of farm lands is being driven via renting. Large scale farming is needed to get the efficiency out of the machinery layer. At the same time, land prices don't allow farmers to buy land and make money. Hence, renting is the only option. For the financial industry, this poses a challenge. In the past, operating capital for farmers has come from hard assets. But, as both equipment and land move towards leasing, it is becoming challenging for asset-light farmers to get access to sufficient credit. These producers are underserved by traditional, asset-based lenders and will want to move towards output/crop-based lending models.

Trade credit providers plug a lot of this gap. However, for farmers this may not be the best solution, as they are not able to bundle their financial needs and get the best interest rates. FarmOp Capital allows farmers to bundle their financial needs based on an outcome-based model. In addition, funding is independent of input providers and provides farmers with operational independence.

As a consequence of our business model, we have to bet on farmers that farm efficiently. Hence, rather than maximizing input sales, our focus is on driving efficient and sustainable farming practices, as they have the potential to drive margin. For example, FarmOp Capital is perfectly placed to finance the transition of farmers from GMO to non-GMO production. Tiling is another good example that we can finance without blocking the financing capability of a farmer's hard assets.

5. A technological race with uncertain outcomes

Our views on key technologies

With the large number of competing technologies and companies involved, sorting through the pros and cons of precision agriculture technologies can be a difficult task. To help with this, we spoke to over 30 international experts in the field to get their insights on where some of the key technologies will be able to create value.

One of the key questions, at least from an agricultural OEM point of view, is around the validity of swarm solutions. The basic idea is to replace one high-powered tractor with many lower-powered "swarming" ones. These infield robots or tractors are wirelessly connected to a central operator to receive real-time instructions for required operations. A number of concepts for seeding (XAVER by AGCO) and weeding (Bonirob by Bosch) operations have already been demonstrated.

As swarm vehicles can scale more easily, the number of tractor operators can be further reduced, addressing a key farmer pain point. In addition, the failure of one swarm vehicle is less catastrophic when compared to the failure of a large tractor. In principle, swarms can cover both small and large farms well by simply adding or subtracting numbers to the existing fleet. Their lower weight will be beneficial for soil compaction and may lend itself more easily to electrification. Lastly, the greater number of swarm vehicles would allow a complete redesign both from an engineering and a manufacturing perspective, while ushering in a transition similar to what is expected in the air taxi (UAM) space in the aerospace industry.

Still, swarm technologies come with their own set of challenges. Energy densities and operational parameters such as fuel usage are chief among them and haven't been entirely solved. That said, Japanese OEMs are the leaders in this technology so far given the country's unique position in an aging and shrinking population in rural communities.

Moving forward, we expect weeding and pest management applications to reach commercial maturity over the next 3–5 years, followed by seeding and then field preparation solutions. However, we do not see large tractors losing their appeal anytime soon, especially for field preparation of row crops.

Another discussion centers around the validity of in-ground versus in-vehicle sensors. In-ground sensors are typically static and analyze inputs such as soil type, compaction, moisture levels, and nutrition. They provide farmers with important input to make key decisions. Although the technology has evolved to capture a variety of information, complexity and accuracy concerns have resulted in slow adoption so far.

In-vehicle sensors, on the other hand, are dynamic sensors that are fitted in the vehicle to give soil and crop health information on-the-go. These sensors mainly use imaging technology to gather inputs for further analysis. Although the technology is more advanced in comparison to in-ground sensors, reliability and operational speed remain a challenge. Current in-vehicle sensors with integrated application controllers need a certain amount of time for measurement, integration, and adjustment, which decreases the vehicle operation speed.

Precision agriculture technologies are developing at breath-taking speed. Portfolio management and partnerships are key.

Product-centric organizations need to take the challenge of moving to outcome-based business models head-on. Luckily, successful examples exist in related industries.

From their current application in soil type, compaction, and moisture monitoring, we believe in-ground sensors will move towards soil nutrient sensing and phenotyping over the next several years. Similarly, in-vehicle sensors will go beyond their current application of yield mapping and soil sensing into crop stress and weed detection, pest detection, and ultimately an autonomous agronomist solution. Long term, we expect in-ground sensors to be replaced by in-vehicle sensors as the technology improves.

Satellite technology has also shown significant progress for imaging applications. For example, remote sensing is used successfully to detect variability in soil and crop conditions and to match inputs such as water, seed, and fertilizer via variable rate technology. Currently, satellite imaging technology is more suitable for large areas due to its cost effectiveness in comparison to drone-based imaging. However, with a number of high-precision satellite launches being planned, we expect that precision capabilities will improve significantly to enable usage for medium-sized and small fields.

On a related note, drone-based imaging has evolved rapidly over the last few years. Current drone imaging favors usage of smaller farms where satellite imagery isn't cost effective. With the improvements in satellite technology described above, however, drone-based imaging may be limited to certain conditions such as heavy cloud cover or difficult terrain. With regards to precision spraying, however, drones may prove to be a significant advantage as payload capacity continues to increase.

Electrification in large agricultural equipment is still in the concept stage. Here, power availability in the field and productivity losses due to longer charging times (as well as limitations on power density), will likely result in slow adoption of electrification as an alternative powertrain. Implement electrification in equipment such as sprayers, seeders, and planters, however, is a growing trend driven by efficiency and precision benefits.

Lastly, farm management systems are another interesting area in the precision agriculture landscape. They assist farmers and land managers in achieving higher yields and less waste through smarter resource management and greater reduction of input costs. Current farm management systems use predictive algorithms to issue warnings on imminent pest attacks and other key risks affecting farm productivity.

In the future, we believe farm management systems will continue to increase accuracy and customization for specific farms and crops. This trend will first occur with large crops such as corn and cotton. In the mid to long term, these systems may shift the current agronomist advisory to a more machine-based model which uses both machine learning and prescriptive analytics.

6. Navigating agriculture's transformation successfully

Some thoughts on how to move forward

Precision agriculture is the future. It is a key ingredient to ensure sustainable food supply to a growing global population. Established companies and new entrants in the space evidently see a great opportunity ahead. We do too. Yet many incumbents face challenges in realizing their future potential by leveraging their scale and experience in this critical industry transition.

To that end, we believe that five clusters of questions must be answered compellingly in order to succeed:

1. WHERE TO PLAY AND HOW TO CREATE VALUE?

As agricultural solutions move towards globally integrated platforms, how do we decide which part of the value chain to own? How do we create value? Which capabilities do we need to own and where is it smarter to partner? Which parts of our old business model don't work anymore and need to be replaced with new, more flexible approaches?

2. HOW TO MOVE TOWARDS OUTCOME-BASED BUSINESS MODELS?

As the business model moves away from being product-centric to outcome-based, how do we manage this transition? What are relevant time scales? How do we prioritize investments in the "old" product world vs. the build-up of new outcome-based business models? How do we organize and incubate a different mindset?

3. HOW TO LEVERAGE TECHNOLOGY?

Considering the fast pace and globally dispersed technology development, how do we keep up and stay on top of developments? What's the best way to integrate and leverage the opportunities that we have identified?

4. WHAT ARE WINNING PROPOSITIONS FOR FARMERS?

With farm incomes depressed, high debt, aging farmers, and significant political uncertainty, how do we create a value proposition for farmers that makes the most sense? How do we co-develop and create a fair value distribution?

5. HOW TO ENGAGE THE EXTENDED ENVIRONMENT?

With increased activism (environment, data, investors) in the agricultural space, how do we best engage? How do we address challenges that are being raised and communicate our activities effectively?

Potential solutions for these challenges do exist. Similar to other industries that are faced with multiple technology and business model disruptions, players in the precision agriculture field need to take some unconventional steps.

First, a critical look at future core competencies is necessary. An understanding of the required investments to build or acquire these core competencies must be developed. Based on this understanding, companies must evaluate how they can finance the transition from old core competencies to new core competencies. Even more importantly, a decision must be made on how to manage the transition phase itself, during which both sets of competencies need to be supported.

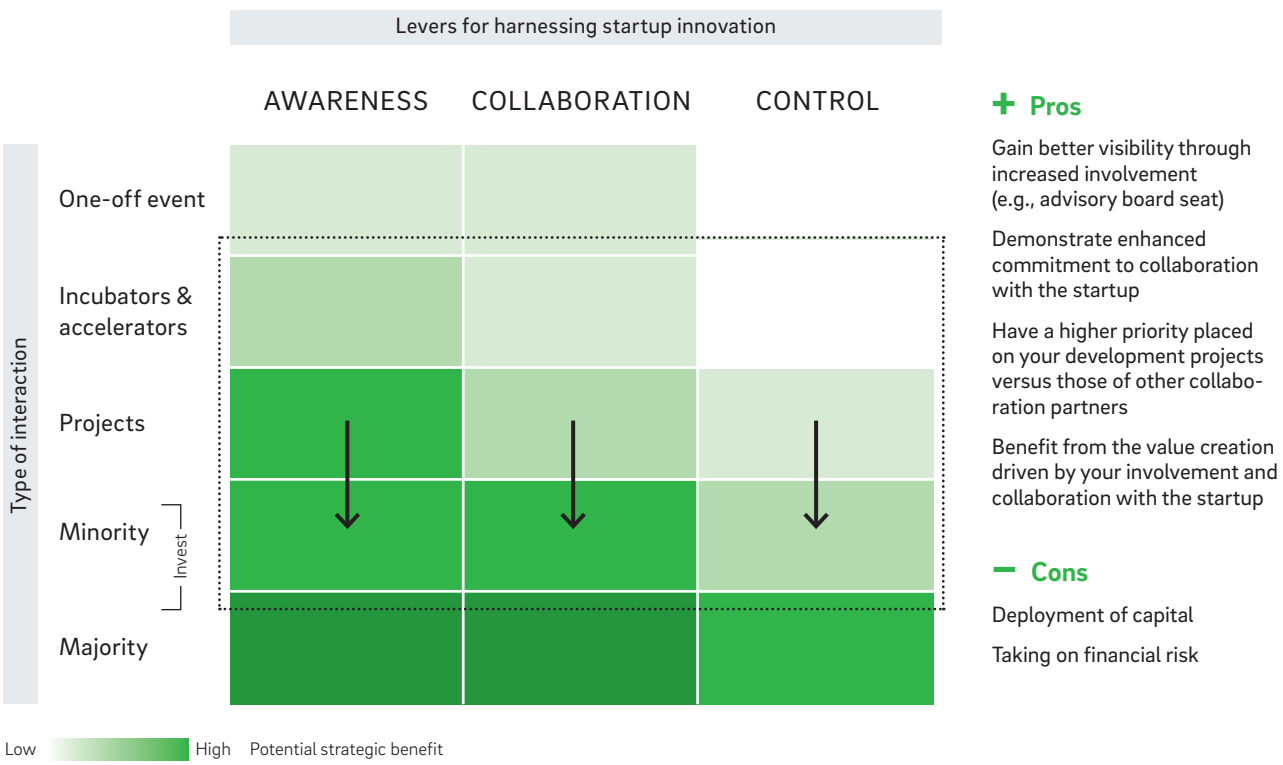
Accordingly, resources need to be pooled across industry participants and potentially between competitors. The recent collaboration between BMW and Mercedes on seats is a good example. Other examples include the recently announced cooperation between Ford and Volkswagen, and the concentration of General Motors on its core markets (the U.S. and China) and withdrawal from India and Europe.

Organizational structures and incentives must also be realigned. In extreme cases, some companies have decided to build their new delivery organization in parallel to existing ones to ensure that the former can flourish unencumbered by the latter.

Furthermore, engagement with startups and other ecosystem players must be fostered. Options for such engagements span the full range from loose association to majority ownership. Depending on the importance of a particular company's capabilities, any of these engagements can create value. → L

In our view, increased focus must be placed on outcome-based business models. This is a difficult transition, especially for large OEMs, since revenue and profit opportunities are often not comparable to the existing business. It is better to disrupt and/or self-cannibalize your own business model, however, than to be usurped by someone else.

L: Corporations gain strategic value from each type of interaction, but acquiring a minority stake can provide control and closer collaboration
Incremental benefits from investing in startups – Minority share



Source: Roland Berger

Conclusion

Precision agriculture is undergoing rapid transformation from both a product and a service perspective. Technological disruptions, business model transformations, and organizational changes are all creating an exciting but challenging opportunity. In light of smart sensors, modern biologicals, robotic automation, and digital data, many large incumbents have recognized the need to adopt Farming 4.0 and have correspondingly invested in their own respective futures.

In truth, many agricultural companies are facing the same kind of pressure as cash-strapped and traditionally risk-averse farmers. Obviously, the required investments, technological uncertainty, and organizational risks are high. While we know that not every company will successfully master this transition, those that do will drive sustainable food production for the world.

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WE WELCOME YOUR QUESTIONS, COMMENTS AND SUGGESTIONS

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