EQUITY RESEARCH | July 13, 2016

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Innovation flourishes where there are big problems to solve, and few problems are as large as the need to feed the world. In the latest in our **Profiles in Innovation** series, we explore how agriculture offers fertile ground for a confluence of technology trends, from sensors and the Internet of Things to drones, big data and autonomous driving. We see the potential for Precision Farming to lift crop yields 70% by 2050 and create a $240 billion market for farm tech, adding to agriculture's long history of holding off a Malthusian crisis.

PROFILES IN INNOVATION

Precision Farming

Cheating Malthus with Digital Agriculture

The Goldman Sachs Group, Inc.

Contents

PROFILES IN INNOVATION

This is the fifth report in the *Profiles in Innovation* series analyzing emerging technologies that are creating profit pools and disrupting old ones. Access previous reports in the series below or visit our portal to learn more and see related resources.

- Virtual and Augmented Reality
- Drones
- Factory of the Future
- Blockchain

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PRECISION FARMING in numbers

A CHALLENGING SCENARIO

9.7bn Expected world population by 2050, translating into 70% required growth in global food supply from current levels. (p. 5)

58yrs Average age of a farmer (in years) in the US – a number that has consistently moved up over the past 30 years. (p. 14)

40% Percentage of grain consumption in 2015 that China – the world's most populous country – imported. (p. 5)

CURRENT PRODUCTION

$1.2tn Global crop production value in 2015. (p. 8)

THE HUGE OPPORTUNITY

70% Potential tech-driven improvement in yields by 2050. (p. 7)

$240bn Total addressable digital agricultural technology market. (p. 8)

WATER WASTED

>90% Proportion of irrigation outside the US using flood method resulting in loss of efficiency. (p. 29)

50% Potential reduction in water waste with precision irrigation systems paired with water sensors. (p. 28)

IMPRECISE APPLICATION OF INPUTS

40% Percentage of over-fertilized fields. (p. 20)

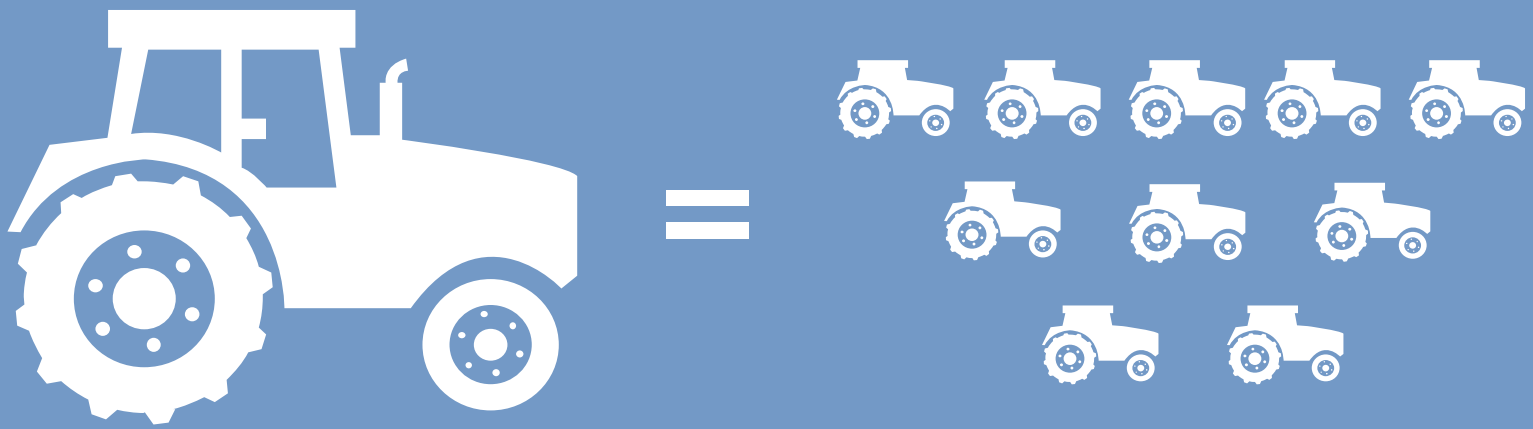
15%-20% Yield loss suffered from inadequate fertilizer application. (p.20)

LIGHTER ON THE SOIL

Manual vs autonomous tractors

One 600hp tractor weighing ~45,000lb

Ten 60hp autonomous tractors weighing ~5,000lb each



Precision Farming: Cheating Malthus with Digital Agriculture

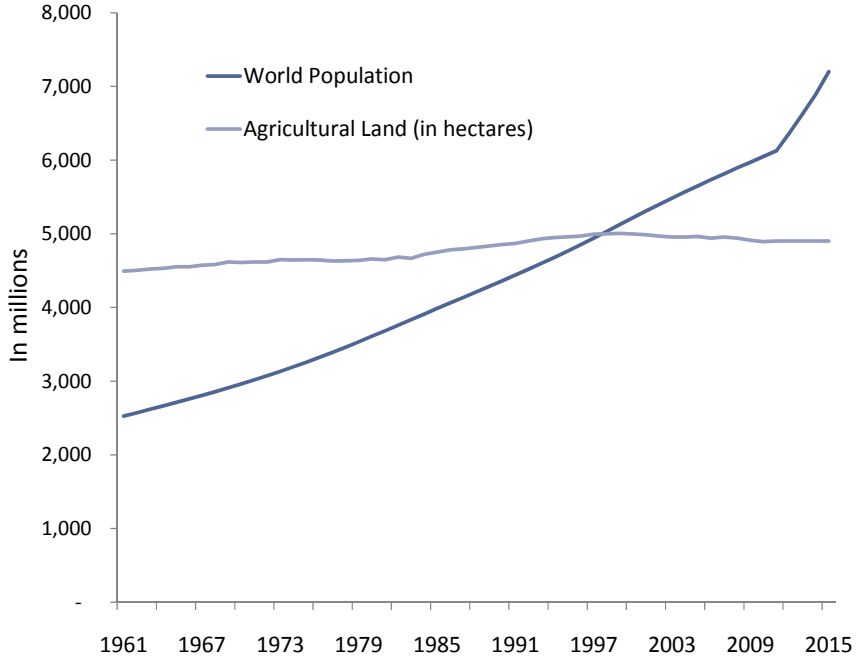
Farming has long been a proving ground for the adage "necessity is the mother of invention." From the introduction of the steel plow and reaper over 200 years ago to modern advances like large scale planters and genetically modified seeds, man continues to find new ways to feed the world's growing population. As we near the limits of available arable land, a confluence of technologies is driving a new leg of productivity in Precision Farming to enable growers to meet the demand challenge from existing land.

A problem of Malthusian proportions

The world has a long-term food supply challenge. And according to the modern day Malthusians, it's a problem that mankind can't solve. But we've been here before many times. Thomas Malthus was an 18th century scholar and cleric who argued that population growth is exponential while food growth is arithmetic, resulting in an inevitable period of food shortage. His theory garnered a lot of attention not the least because it spoke to a core need and fear. But it has been wrong so far as human ingenuity and economic incentives have driven a stronger supply response. And we think the modern day doomsters are wrong again. However, their diagnosis of the problem is right: the world faces a substantial challenge to feed itself in the face of an expanding population, growing demand for protein as incomes rise, and a geopolitical mismatch between food supply and demand.

But our research suggests that they are wrong in arguing that there is no solution. Our conviction is reinforced by more than 60 field interviews (often literally in a field) with farmers, academics, venture capitalists, dealers, start-ups, and established ag and technology players. We think yields can rise by over 70% to 2050. How in a world of falling arable land per capita is this possible? Our answer is the end of the analog age for farming. Advances in hardware, software, computing power enable far greater precision in planting, fertilizing and irrigation. The extension of technologies such as autonomous vehicles, drones, and logistics management systems add to this transformative confluence. In this report, we detail our field research on precision farming solutions under development. New winners and losers will emerge from this shift to digital agriculture, as will new entrants who want a slice of a total addressable market growing to $240 bn by 2050.

Exhibit 1: Farm productivity improvement is critical as available land per capita declines
Global arable land acreage vs. population



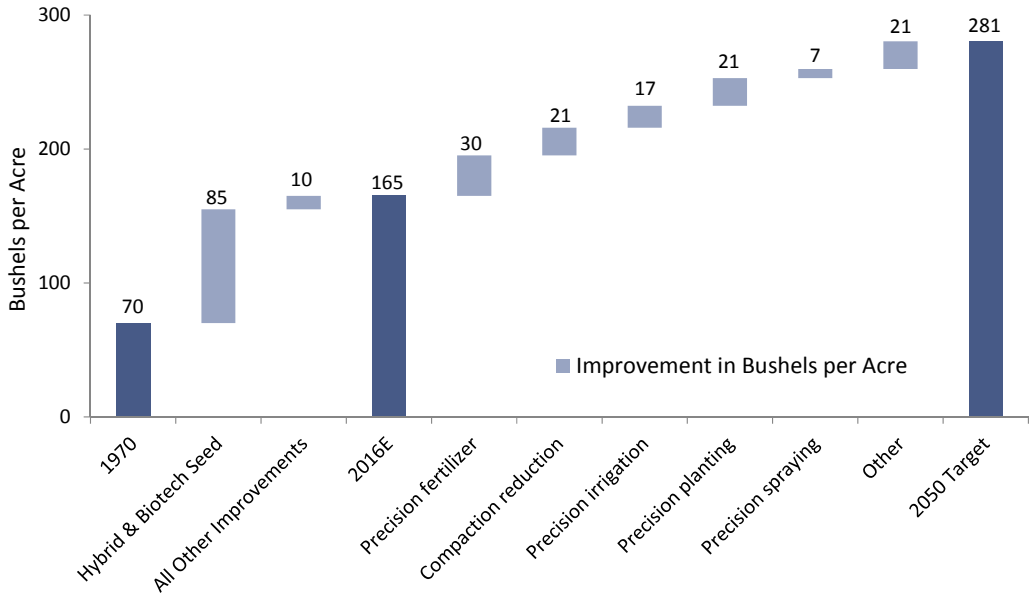
Source: Goldman Sachs Global Investment Research, FAO.

Meeting the need for a 70% increase in food production over the next 35 years

In 1798, Thomas Malthus concluded that population growth will eventually be constrained by food supply. At the core of Malthus's theory are two issues: First, population growth is exponential while food growth is arithmetic. Second, with rising incomes comes rising food consumption per capita – a dynamic that is now evident in meat consumption per capita growth of 1.2% – a significant challenge considering every pound of meat requires two to seven pounds of grain feed. Since the publication of the Malthusian theory in 1798, the world has found a way to cheat the theorem through a combination of basic supply response (acreage additions) and innovative breakthroughs (genetic seed development). A bevy of new technologies is now starting to pervade the farm that we believe has a central role in ensuring humanity cheats Malthus again over the next 100 years.

The Food and Agriculture Organization of the United Nations (FAO) estimate population growth of 35% over the next 35 years. Assuming current the growth in per capita protein consumption (+0.5%), we estimate a 1.5% CAGR in food supply growth would be required over that time period to match demand. Unlike during the 1800's when demand growth was met with acreage increases, the FAO estimates a modest 4% increase in available acreage over the next 35 years, which might be optimistic with the growth contingent on expansion in Sub-Saharan Africa. So the next 70% food production growth has to come from yield.

Exhibit 2: Seed advancement has driven yield growth over the past 40 years
US corn yield drivers



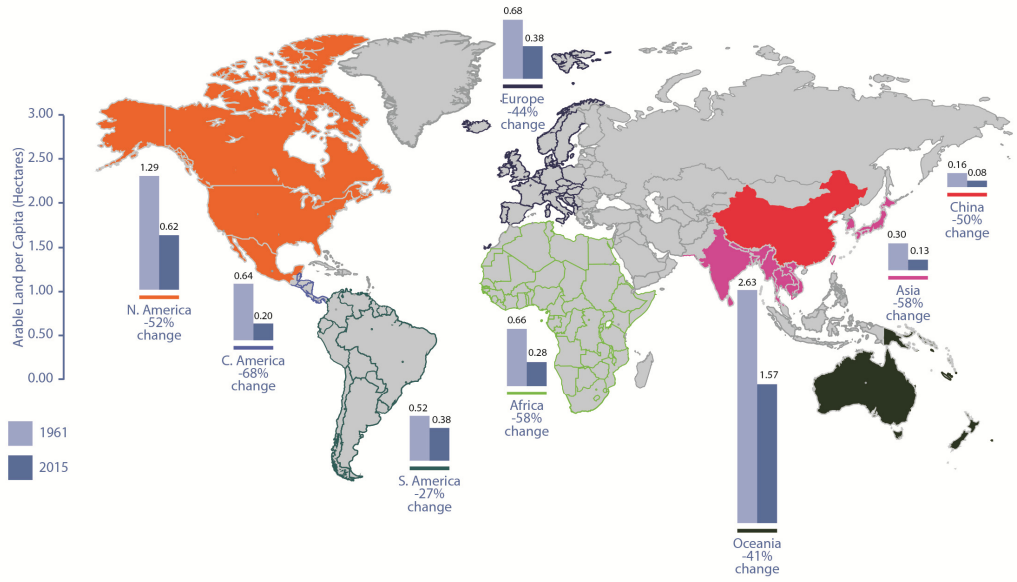
Source: Goldman Sachs Global Investment Research, USDA, Company Data

Geopolitical pressures provide a new challenge for the current Malthusian cycle

Adding to the population growth challenges in this cycle is a growing physical disconnect between population and farming basins – factors that are driving geopolitical considerations. China's consumption of mined commodities over the past 15 years is well understood; however, China's domestic food production issues have not hit the mainstream. Following 40 years of modest net food exports, China has moved significantly into net import territory over the past seven years. In 2015, China imported 40% of its grain consumption (See Fortnightly Thoughts, September 17, 2015). The primary driver of this change is the growth in per capita protein consumption, which in China is up 150% since 1990. As a result, Chinese focus on acquiring foreign farmlands has significantly increased; last year, Australia blocked the purchase of 25 mn acres of farmland by Chinese companies

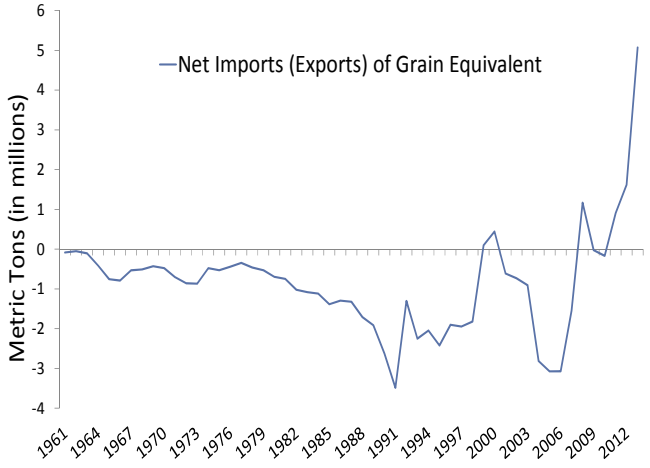
– a land mass equivalent to the size of Kentucky[1]. Chinese companies have also acquired farm land in Congo, Mozambique, and Angola (fish)[2]. Saudi Arabia has increased its focus on US farmland purchases to grow water-intensive crops such as alfalfa so as to conserve local water supply[3]. A rising focus on national food security should be supportive of farm technologies that are focused on maximizing yield, which we explore in this report.

Exhibit 3: Arable land is concentrated in Oceania and the Americas, creating a mismatch vs. population distribution
Arable land per capita



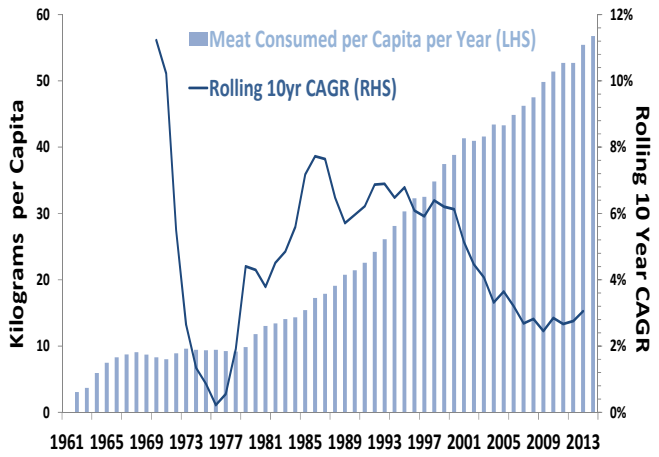
Source: Goldman Sachs Global Investment Research, FAO.

Exhibit 4: China faces a significant food import position
China net import (export) position for grain and meat (in grain equivalent units)



Source: Goldman Sachs Global Investment Research, FAO.

Exhibit 5: Meat consumption per capita in China is now growing at 3% per year
China meat consumption per capita



Source: Goldman Sachs Global Investment Research, FAO.

[1] http://fortune.com/2015/11/19/australia-just-stopped-china-buying-a-farm-the-size-of-kentucky/

[2] https://www.washingtonpost.com/news/wonk/wp/2015/05/21/rich-countries-are-buying-up-farmland-from-poorer-ones-around-the-world/

[3] http://www.cnbc.com/2016/01/15/saudi-arabia-buying-up-farmland-in-us-southwest.html

How has humanity cheated Malthus over the past 200 years?
Malthus originally predicted food supply-demand would reach a tipping point by 1830. However, global population increased to 1.65 bn at the end of the 19th century, up 70% from the time of Malthus's original theory of 1798. We identify three levels of innovation that have driven food supply growth over the past 200 years, and we expect precision farming to be the fourth.

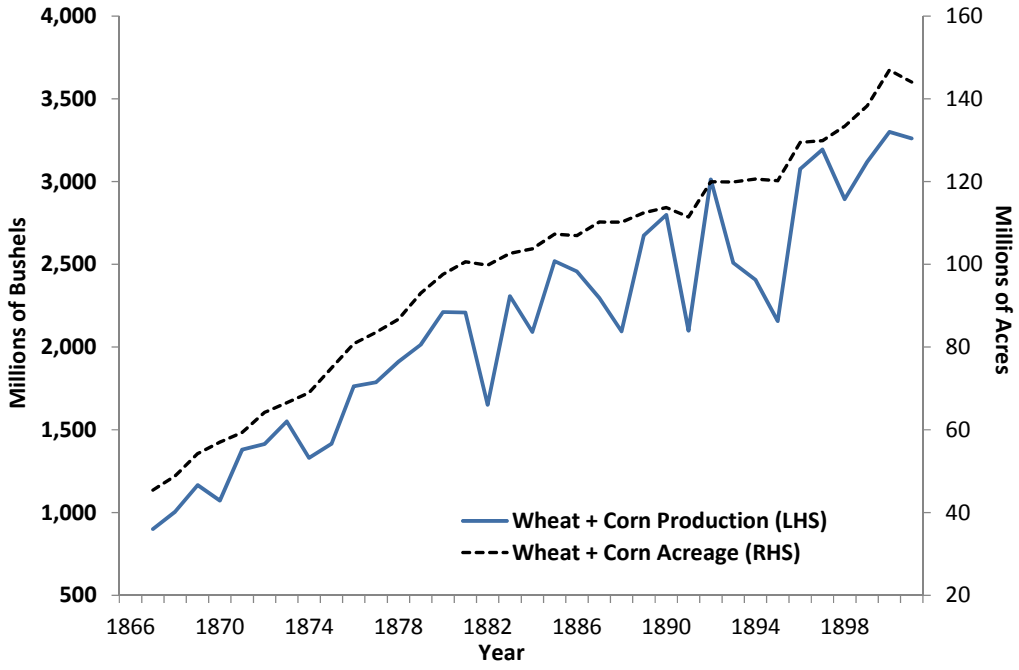
(1) **Farm acreage growth and mechanization**. Food growth through the 19th century was driven largely by significant acreage growth. In the US, for example, corn and wheat acreage nearly tripled to 130 mn acres in 1900 from 45 mn acres in 1860 (Exhibit 6). Farm mechanization was a key enabler – including products commercialized by Deere and McCormick – allowing farmers to access more land while actually reducing the size of the labor force.

(2) **Green revolution**. The 20th Century was marked by the "Green Revolution" – transplanting cereal crops into new regions, including wheat into Asia and Mexico.

(3) **Seed genetics and hybrids**. The past 40 years marked transformative progress in seed genetics, led by Monsanto, DuPont, and other seed producers that oversaw more than a doubling in yields.

(4) **Precision farming to drive the next leg of supply growth**. As outlined in Exhibit 2 and detailed in the rest of this report, we believe precision farming is key to driving the next leg of supply growth, with 70% yield improvement from a combination of precision planting, fertilizer application, irrigation, spraying, and autonomous driving applications. We would expect adoption to start in developed markets, consistent with the adoption curve of precision ag GPS, as returns on the investment and labor costs are both higher.

Exhibit 6: Food production growth in the 1800's was driven by acreage growth
US corn and wheat acreage vs. crop production



Source: Goldman Sachs Global Investment Research, USDA.

Harvesting the numbers: What are the building blocks that can move farming from analog to digital?

Software services supplier view: "Our findings show that farmers who don't use precision fertilizer technology are over-fertilizing 40% of their fields, yet suffer yield loss on 10% of the fields."

Over the course of over 60 field interviews, we've focused on identifying and evaluating the impact significant emerging technologies could have on global crop yields. We view the crop yield metric as the ultimate value of each technology area that we explore in this report. Based on a global annual crop production value of $1.2 trillion in 2015 and our bottom-up estimate of technology-driven yield improvement of 70%, we estimate value generated of $800 bn if all of the technologies are fully adopted globally by 2050. Based on historical capture rates of 30% for seed producers – the last major ag productivity cycle – we estimate a total addressable market of $240 bn. The actual value capture will depend upon how the competitive environment evolves, as some industrial products have captured as low as 15% of value-added. In the truck manufacturing industry, for example, manufacturers improved truck fuel economy by over 10% in 2015, saving truckers $15,000 over five years; however, pricing on the new product amounted to only a $2-3,000 realized price increase, or 13-20% value capture. The major components of the $240 bn profit pool (based on 30% value capture) are as follows:

Farmer: "Multi-hybrid seeding will revolutionize farming practices and have a step-change impact on my yields;"

- **Precision fertilizer application**: $65 bn addressable market based on an 18% increase in yields. To take precision fertilizer application to its maximum level of impact, a broad range of hardware and software will have to be integrated. Key hardware includes tractor-mounted fertilizer sensors and applicators, drone data, satellite data, weather data analysis, and ultimately data analysis integration software. Companies well positioned with relevant technologies include Trimble, Monsanto, aWhere, Raven, FarmSolutions, FarmersEdge..
- **Precision planting**: $45 bn addressable market based on a 13% improvement in yields. Required technologies include multi-hybrid planters and data aggregation and analysis software. Companies that currently offer the products or components include Deere, Great Plains, Raven.

Academic view: "Over the past 20 years farm equipment has gotten bigger and bigger. But that size has a cost to it – greater soil compaction reduces yields by over 15-20%."

- **Compaction reduction via a fleet of smaller tractors**: $45 bn addressable market based on a 13% yield improvement. Autonomous driving technologies will have to be developed to drive this shift – companies that stand to benefit in this value chain include MobilEye, Bosch, Delphi, Conti, TRW, Quanergy.
- **Precision spraying**: $15 bn addressable market based on a 4% improvement in yields. Integration of field monitoring with on-the ground hardware is required to deliver the improvement. Current companies that offer commercial products include Trimble and Raven.
- **Precision irrigation**: $35 bn addressable market based on a 10% improvement in yield. Current providers include T-L Irrigation and Lindsay Corporation.

What are the emerging unknowns in precision farming?

Significantly higher value added from the "knowns" than we expected: mass customization to the individual seed yields significant resource savings. Fertilizer sensors on the front of the tractor can now evaluate fertilizer levels on every square foot on a field, driving a signal to the storage tank to apply the optimal level of fertilizer. A planter can now automatically plant more seeds at the part of the field that has the highest yield. At more susceptible parts of the field, the planter can now not only reduce the seed count, but switch to a "defensive" variety for pre-programmed areas. Precision irrigation systems paired with water sensors improve yields by 10% while reducing water waste by up to 50%. We believe the result of mass customization will be a new and growing industry of technology enabling components, shrinking value capture for some incumbents – fertilizer suppliers – and product cycle risk (and opportunities) for hardware manufacturers.

What are the unknowns that could have dramatic outcomes?

- **Who can develop the killer app?** Data is everywhere, but who can harvest it? Who can design the app on the farmer's smart phone– integrating basic functionality in an accessible way that builds a network effect and drives innovation. We've come across a few companies that could be well positioned – Trimble, FarmersEdge, potentially Raven. Deere's strategy will be interesting to monitor – to date Deere has focused on maximizing operability with an "all green" fleet. For all of the yield improvement benefits in the knowns, the critical underlying assumption is the processing and integration of data for access. This might be done by existing players (Trimble, Deere, FarmersEdge), startups, or large scale existing players (IBM?).

Farmer: "We run our Brazil operations on small equipment to avoid compaction, and we have labor costs coming out the ears."

- **Can autonomous tractors gain traction before autonomous cars?** Autonomous driving technologies are nearing commercial levels for car applications. But exception processing requirements are significantly more onerous on public roads with a range of random, uncontrollable variables. The farm on the other hand is a significantly more controlled environment with a finite field and repetitive set of actions. Based on our field work on autonomous vehicles (*see Cars 2025: Monetizing the rise of Autonomous Vehicles*) we expect total system costs to be $3,000 per unit. Soil experts estimate large tractors and combines reduce field yield by up to 13% due to soil compaction. A shift to a fleet of smaller automated tractors should therefore improve farmer revenue by 13% as a result and could further reduce farm labor costs. The result could be a shift in industry capital stock to a fleet of significantly smaller equipment – making the software behind the hardware the key to value capture.

  Companies with enabling technology argue that an operator is ultimately needed to refill various farming inputs (fertilizer levels, seed) and monitor hydraulics. But a key question is whether a single technician can operate an entire field of equipment, monitoring data feeds from a central location, freeing up tractor drivers for other projects? If this situation plays out, leading equipment manufacturers will have to participate in the driverless value chain to maintain their market positions.

- **Governments could fund satellite and drone data**. The biggest impediment to broader adoption of satellite and drone data feeds is cost, particularly for satellites. The issue is greater scale is required to drive costs to levels that provide adequate farmer returns, and the implementation process can be iterative and lengthy in an extremely fragmented global farming industry. Currently farmers in adjacent fields can have different satellite and drone service suppliers, even though the entire data feed can be captured by a single data run. Governments concerned with food availability can shorten the adoption curve by funding data runs at the national level, with large contract bids to service suppliers.

How will the spoils of humanitarian progress be divided?

Based on the adoption of precision farming technologies, we forecast a 70% increase in crop output to feed the world's forecast population growth through 2050, generating $800 bn in additional crop revenue per year at current commodity prices.

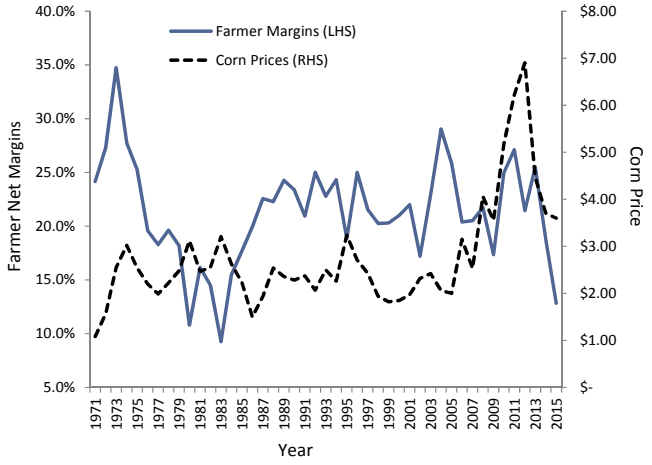
Humanity wins. 70% crop production growth is enough to sustain 35% projected population growth AND provide for higher levels of nourishment per capita. The current number of people undernourished globally is 792 million according to the FAO, which is down 25% over the past 20 years. If the world is able to grow food production ahead of population growth by adopting Digital Farming technologies, we believe a further progress on improvement in nourishment per capita is likely.

Will farmers benefit or pass through gains to the consumer? The answer is likely to vary by year, but we expect current farm land owners will ultimately achieve 70% higher volumes, albeit at comparable margins to the historical cyclical range. In the US, over the

course of the corn ethanol cycle, for example, farmer margins improved from a trough of 17% to a peak of 27%; now that supply has caught up (and overtaken) ethanol demand, margins are back down to 13% even though yields and demand are both up significantly off the 2002 trough. If history is a guidepost, over time farmers should benefit from higher sales, but margins are likely to remain as deeply cyclical as they have been for the past 40+ years of reliable data.

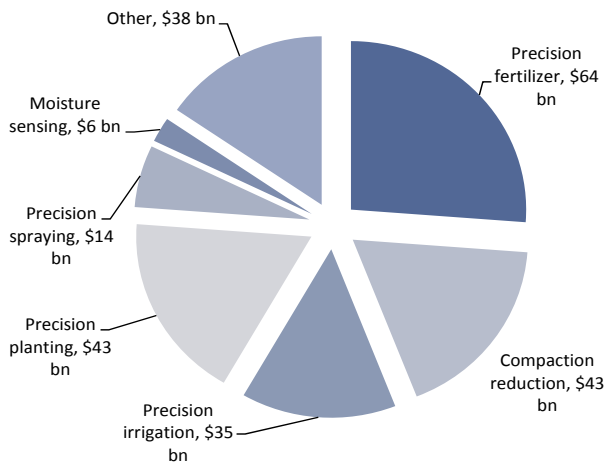
In a gold rush, sell shovels. Technology leaders with sustainable competitive differentiation are well positioned to benefit from rising penetration rates on precision farming applications, in our view, as (1) current revenue from precision farming applications is minimal while R&D spending is significant, (2) subscription revenue base and manufacturing business models both benefit from rising absorption as adoption grows. The risk of new entrants though is clearly not zero, particularly in data processing.

Exhibit 7: US farmer margins have remained deeply cyclical, despite the US ethanol cycle
US net farm income margins



Source: Goldman Sachs Global Investment Research, USDA.

Exhibit 8: We estimate a $240 bn potential addressable market for Precision Farming
Precision Farming addressable market by technology



Source: Goldman Sachs Global Investment Research.

What's the best part of the value chain with improving competitive barriers?
We believe the key to extracting value from the Precision Farming value chain will be clearly quantifiable product IRR to the farmer, access to data, significant competitive differentiation, and access to distribution. In our views, precision planting has the most significant near-term appeal in terms of providing a clear ROI and a value proposition that's intuitive to the farmer – varying the seed planted based on the characteristics of the field without disrupting planting speed. Companies supplying and integrating data across multiple Precision Farming applications – Trimble, Deere, Raven, Hexagon, Monsanto – benefit from a growing competitive advantage as the level of farm interoperability rises. Cost-effective access to distribution – via direct dealers, agronomists, or other trusted channels – is critical due to scale benefits and significance of product support for farmers during short planting and harvest windows; Deere and Trimble stand out. Page 12 outlines companies with significant offerings and includes public companies AGCO, CNH, Deere, Hexagon, Lindsay Corp., Monsanto, Topcon, Raven, Delphi, Mobileye, TRW.

Who in the value chain is at risk?

- Global fertilizer demand could decline by up to 4% as precision fertilizer case studies have revealed significant amounts of fertilizer run-off and over-application in saturated fields. Monsanto estimates a 10% reduction in fertilizer application on 40% of the

farmers' field, equivalent to total reduction in consumption of 4%. In a commodity industry with fixed acreage and declining application rates we think the long-term fertilizer margin outlook is likely to remain challenged.

- Bigger has been better for the past two decades in world class farming operations. However, if the scenario of smaller autonomous driving farm equipment plays out, Deere and (to a lesser extent) CNHI would have to deliver best in class integrated autonomous driving technology to maintain their dominant market positions in high horsepower applications. For some high horsepower equipment categories, Deere and Case have a combined nearly 85% share; the market for tractors under 100 horsepower tractors, on the other hand, is severely fragmented, with a broad range of competition from Mahindra, Kubota, AGCO, among other players.
- Execution risk for farmers. Farmers that are slow to adopt technologies with high returns face the specter of seeing their yields remain flat while higher yields for neighbors adopting technologies drive commodity prices lower.

The Ecosystem

Precision Farming-Key Players

A sample of companies with exposure to enabling technologies

Precision Fertilizer

Key Enablers

Monsanto Climate Corp
Trimble
Hexagon Agriculture
Raven
Agrium
aWhere
DuPont
FarmersEdge
Adapt-N
FarmSolutions

Precision Planting

Key Aggregators

AGCO
Case New Holland
Deere
Hawkins Manufacturing
Kinze

Key Enablers

Trimble
Raven
Hexagon Agriculture
Great Plains Manufacturing

Precision Spraying

Key Aggregators

AGCO
Case New Holland
Deere

Key Enablers

Trimble
Raven
Equipment Tech
Hexagon Agriculture

Compaction Reduction Via Smaller Tractors

Key Aggregators

AGCO
CNHI
Deere
Bosch
Continental

Key Enablers

MobilEye
LeddarTech
Quanergy
Delphi
TRW

Precision Irrigation

Key Aggregators & Key Enablers

Lindsay Corp
T&L Irrigation
Trimble
Common Sensor
Jain Irrigation
Rain-Tal Ltd.
Saturas Precision Irrigation

Field Monitoring

Key Aggregators

Trimble
Deere
Raven
FarmersEdge

Key Enablers

aWhere
PrecisionHawk

Data Management

Key Aggregators & Key Enablers

Deere
Trimble
Monsanto Climate Corp
Topcon
Hexagon Agriculture
FarmersEdge
Ag Leader
Agrian
Crop Metrics
SST Software
Farmlogs

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The Ecosystem

Precision Farming-TAMs and potential value added

Precision fertilizer
$65 billion (TAM)

- $200 billion potential value add
- 18% yield improvement

Precision planting
$45 billion (TAM)

- $145 billion potential value add
- 13% yield improvement

Compaction reduction via smaller tractors
$45 billion (TAM)

- $145 billion potential value add
- 13% yield improvement

Precision spraying
$15 billion (TAM)

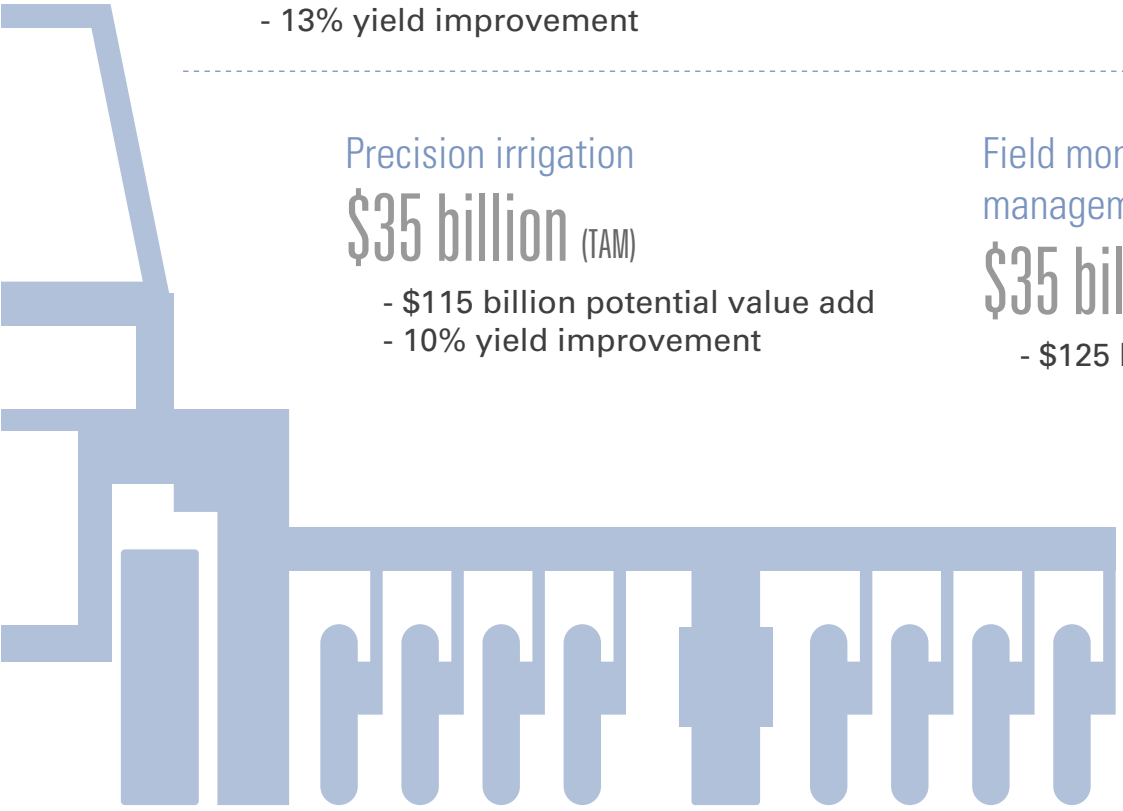
- $50 billion potential value add
- 4% yield improvement

Precision irrigation
$35 billion (TAM)

- $115 billion potential value add
- 10% yield improvement

Field monitoring, Data management & Others
$35 billion (TAM)

- $125 billion potential value add



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From skeptic to believer: our journey

Over the past year, our department has published on a range of technologies in the Profiles in Innovation –autonomous vehicles, internet of things, drones, virtual technology, and robotics. Based on our field interviews with over 60 experts – growers, leading academics, private technology companies, farming input suppliers, equipment manufacturers, distributors, and other stakeholders – we believe that the farm will be the next major industry to "go digital." Farming is currently among the last of the "analog" industries –digital is coming. Some of it is the application of existing technologies – drones, autonomous vehicles, satellite feeds – along with custom farming solutions. Technology confluence combined with accessibility of computing power is transforming farming.

But to say that we started our research process with a skeptical view would be an understatement. We were skeptical on the pace of adoption in a fragmented industry where proprietors are known to be risk averse, particularly when investing their nest egg. In the US, the average farmer is 58 years old and the average age has consistently moved higher over the past 30 years according to the USDA. In Europe according to CAP, only 22% of farmers are under 44 years old. Satellite and drone data did sound interesting, but we doubted it would translate into real investable areas on the farm.

Leading academics highlighted the impact of soil compaction

What really intrigued us in our initial discussions with academics was a discussion on the impact of soil compaction – a 15-20% drag on yields according to the head of a leading ag studies university program. As equipment has gotten bigger to deliver higher productivity and lower labor content amid declining farm populations, the impact on the land is undeniable. In the context of our autos analyst Pat Archambault's strong views on autonomous vehicles, the connection sounded intriguing. The connection firmed up in a conversation we had with a major autonomous vehicle component supplier – what if large tractors were replaced by a fleet of small autonomous tractors that would reduce cycle times, labor costs, and compaction?

Geology differences drive opportunities for variable fertilizer application

We were also surprised to hear from several professors about the range of geology differences even within a single state, and the impact on water and fertilizer run-off. Even advanced farmers were applying too much fertilizer in up to 40%of their fields, while in other parts of the field less than expected amount of fertilizer was being retained. What was less clear from those conversations was how close technology suppliers were to developing relevant sensors. When we asked the head of Trimble's ag business, we were shocked to hear that the industry has an offering that's nearly commercial that places a nitrogen sensor on the front of the tractor and an automatic nitrogen dispenser on the back that's prescriptive in the amount of nitrogen it applies to each part of the field based on the sensor. Why does the tractor need a driver again?

Mass customization via precision planting and irrigation

As the facts from our field work mounted up, our views on the addressable market and opportunity set continued to move higher. The irrigation sales pitch is well understood; the variable rate of water run-off across the field isn't. We learned about planters – the expensive machines dragged by a tractor – that are in development that can plant multiple different types of seeds. How necessary is it? One farmer estimates his yields could improve by 10-15% if he is able to find a data management software package that optimizes where to plant "aggressive" vs. "defensive" hybrids.

At a regional US farm show, we learned about the potential to reduce seed waste by integrating a seed planter with fertilizer injection. We also saw drones with components seemingly held together with duct tape – a far cry from PrecisionHawk as profiled by GS Aerospace & Defense analyst Noah Poponak – but certainly indicative of farmer interest in field monitoring.

Not all of our work yielded fruit

In the interest of full disclosure, not all of our field work was fruitful. But perhaps no part of our field work was as entertaining as seeing a "precision" flame thrower used instead of pesticide in organic applications in Oklahoma.

FIELD NOTES

Views from 60+ experts

Growers

- Terry Jones, Jones Enterprises
  Operates 58,000 farms across Iowa, Oklahoma, Arkansas, Brazil
- Farmers' Business Network - an independent network of thousands of America's most advanced farmers

Public Companies

Trimble, Monsanto, Raven Industries, Hexagon, Deere, FarmersEdge, CNH, Agco, Lindsay, Great American Insurance, Agrium, Kubota

Academics

- Dr. Susan Ustin, UC-Davis, on remote sensing
- Dr. Roch Gaussoin, University of Nebraska-Lincoln on mapping the Phytobiome
- Dr. John Fulton, Ohio State, on precision spraying, data mgmt
- Dr. KC Ting, Univ of Illinois, on automations and data integration
- Dr. Anthony O'Geen, UC-Davis, on deep-soil analysis
- Dr. Scott Shearer, Ohio State, on precision planting, fertilizing, and soil compaction

Dealers

- AGCO
- Case & New Holland
- Deere
- Trimble
- Kubota
- Deutz
- Bobcat

Private companies

T-L Irrigation, aWhere, LeddarTech, Precision Hawk, Farmigo, Podponics, Valley Controls, Pierce, Great Plains Ag, AgroVantage, Pierce, Maverick Drone, TopGan Drone

Technologies discussed

Drones, sensors, automated tractors, precision irrigation, precision planting, data management, satellites, post harvest logistics, flame-thrower weed control …

Farm Show contacts

Johnston's Seed Company, Knutson Irrigation, Salford Group, Wylie Sprayers, Claggs Tractors, Missouri Moisture Analyzers, Biby Ag Equipment, Flame Engineering…

KEY TECHNOLOGIES

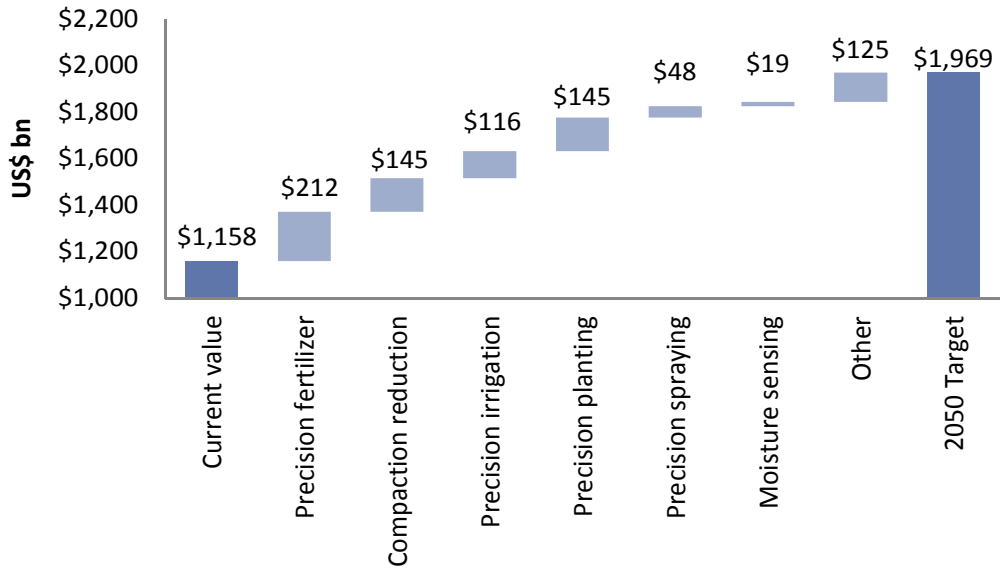
$240 bn addressable market

- **Precision fertilizer application**: $65 bn addressable market, 18% yield improvement`
- **Precision planting**: $45 bn addressable market, 13% yield improvement
- **Compaction reduction via a fleet of smaller tractors**: $45 bn addressable market, 13% yield improvement
- **Precision spraying:** $15 bn addressable market, 4% yield improvement
- **Precision irrigation**: $35 bn addressable market, 10% yield improvement
- **Field monitoring, Data management, and other**: $35 bn addressable market

Technologies changing the face of farming

Following a 4-year period of meaningful excess supply in global soft-commodity markets, the consensus medium-term view is that soft commodities are generally well supplied. However, within the well-publicized context of 1% per year population growth and 0.5% per year growth in meat consumption per capita, we estimate long-term real crop demand growth of 1.5%. Most recently (over the past 40 years), the yield challenge has been met primarily by developments in seed technology – using a combination of genetically modified organisms and hybrid developments (Exhibit 2). However, the pace of precision technology advancement is accelerating, and our field work with over 60 companies and experts drives our view that new technology is now in place to deliver 70% higher yields on existing land. We estimate a total addressable market of $240 bn by 2050 based on total value generation of $800 bn and 30% supplier value capture. In the following pages, we evaluate the primary technology solutions, and potential impacts on existing profit pools.

Exhibit 9: Farming Tech is core to delivering a 70% increase in global crop production
Global crop value in US$ bn's



Source: Goldman Sachs Global Investment Research, Company Data.

A large scale farmer's perspective on Digital Ag

The expert: We spoke with Terry Jones of Jones Enterprises – an operator of over 58,000 farm acres (including partnership acres) across Iowa, Oklahoma, Arkansas, and Brazil. Since 1983, Mr. Jones has been involved in a variety of farming operations including livestock, row crop, and post-harvest activities. Mr. Jones' real-world view of the feasibility of precision ag follows.

- **Precision planting**. Mr. Jones highlighted precision planting as the lowest hanging fruit available across a range of technologies. The first step in precision planting is using a multi-hybrid seeding planter that allows a farmer to load up the larger planter at the rear of a tractor with two different types of seeds – one for parts of the field with poor water or nitrogen retention attributes and one for the more fertile parts of the field. In test runs, Mr. Jones reports a 12 bushel per acre improvement in corn production. At $3.50 corn, the planter delivers an incremental $42 per acre, and with the average planter covering 3,000-3,200 acres, the incremental revenue opportunity from the technology is $130,000. That compares to a total prior generation planter cost of $230,000; even if new planters sell at a 50% premium, the investment would represent less than a one-year payback. So what's holding back adoption? The multi-hybrid planter is only available from Kinze – Mr. Jones' chosen supplier – in a smaller 16 row configurations, while Mr. Jones' operation is set up for a 24 row planter. We see yield improvement beyond the 7-8%from multi-hybrid seeding, as we expect data integration to further improve the planting algorithm from the new technology.
- **Precision fertilizer application**. The Jones Enterprises team is evaluating Monsanto's Climate Corp product to become more prescriptive in fertilizer applications. The constraint until recently has been application equipment – Mr. Jones notes that over 80% of farmers use anhydrous equipment provided by the ag retailer, making the retailer the key bottleneck in switching towards a precision application process. Mr. Jones notes the returns profile of buying the equipment instead of renting it isn't compelling in comparison to other investment options.
- **Drones**. Mr. Jones has started to use drones services on a limited basis. The cost is $125 per hour, which translates to about $0.31 per acre for a single run. Drone data can help identify problems in the field much quicker than a farming team would be able to cover on foot. Mr. Jones notes others are more optimistic on drones use than he is, but he struggles with the ROI given semi-fixed labor costs.
- **Data integration**. Mr. Jones notes that data integration offerings have been disappointing. The team is positive on johndeere.com, particularly as it relates to driving uptime for the equipment fleet. However, the team is yet to see a commercial offering that pulls together history of field data, weather patterns, fertilizer levels, etc., in a single, usable platform. Mr. Jones indicated many companies claim they can do it until they sit down and discuss the full range of data sources and system requirements.

Is there potential interest in a fleet of smaller, autonomous equipment? We discussed the potential use of a fleet of small, autonomous tractors to avoid compaction. Mr. Jones noted that's exactly the philosophy of his partnership's operations in Brazil, where the operators have opted for higher labor costs (over 500 employees) over compaction. On one of his US operations, Mr. Jones employs five full time employees on an 8,000 acre farm, but notes that the return on their work is limited outside of peak season.

A Technology Enabler's Vision of Digital Ag

The expert: We spoke with Darryl Mathews, Senior Vice President and Sector Head of Trimble's Agriculture, Forestry, Positioning Services and HarvestMark divisions. Trimble's potential contribution to precision ag is across the farm.

- **Precision planting** via variable rate planters allows for farmers to place more seed on productive portions of the field, minimizing seed waste during the planting process while maximizing yield from the best parts of the field. According to Mr. Mathews farmers using the technology plant as little as 25,000 seeds per acre in low yielding areas and 35,000 in the most fertile parts of the field. The net seed use is about neutral, but the yield on that seed moves significantly higher. Penetration rates are low – North America is the highest at 14% – with installations done on an aftermarket basis.
- **Precision fertilizer applications**: Trimble estimates 40% of US farmers use basic variable rate technology for fertilizer applications today, which yields a cost savings of 10% per acre and a yield improvement of 10% on 10-15% of the field. However, the company has recently started selling the GreenSeeker sensor and flow control system. A sensor sits at the front of the tractor, measures and quantifies the variability of the crop, and then creates a targeted nitrogen prescription that is "filled" by the delivery system on the back of the tractor. Adoption of the technology is still in the early stages.
- **Precision spraying.** Trimble has developed a solution that works in Argentina and Australia called WeedSeeker that allows farmers to save up to 60% on spraying costs by identifying part of the field where weed growth is the highest. Unfortunately the product isn't usable in regions with harsh winters. Globally, Trimble's precision spraying offerings allow for a more targeted application of product during regular applications, and offer 8-10% reduction in product waste. Precision spraying has been adopted by roughly one-third of US farmers, leaving room for further market capture.
- **Field monitoring: drones versus satellites**: Trimble sees valuable data provided by both drones and satellites. While satellite companies have brought up the ability to identify problem areas on the field as one key benefit, Trimble management noted that by the time the imagery shows the issue, it's too late to fix the problem. Trimble notes satellite data is helpful for vegetative mapping as one core output. A challenge from using both drones and satelites is the difficulty pinning down the yield improvement, according to management, and consistent with Mr. Jones' of Jones Enterprises views.
- **Precision irrigation** involves (1) soil analysis, (2) weather data integration and (3) water application. TRMB sees an 8-10% increase in harvestable acres as precision irrigation is implemented. With an estimated average investment of $50,000 for a farmer, the payback period is often one growing season.
- **Bringing it all together; an integrated software suite**: Trimble's ConnectedFarm system offers a comprehensive solution to information management in the Big Data era. Trimble's software offering allows for precipitation monitoring, fleet health and location monitoring, mid-season crop reporting, satellite imagery scrubbing, and field profitability calculations. Trimble's offering follows a SaaS model, with an estimated market penetration of 20-25% globally. Trimble notes for basic features, an operator of a 500 acre farm pays $1,500 to subscribe to ConnectedFarm. However, at the high end, subscriptions can be as high as $250,000 a year for a 200,000-300,000 acre farm when more services, including compliance, soil sample analysis and imagery analysis, among other features are included. Management notes penetration is 20-25% globally for basic data services.

Precision Fertilizer Application:

$65bn addressable market, $200bn potential value-add

- Helps optimize fertilizer consumption by varying fertilizer application rates in different parts of the field; improves yield by 18%
- **Technology in use:** Weather & field modeling
- **Upcoming technology:** Mobile sensor and fertilizer application system
- **Major players:** Trimble, Raven, Monsanto, Hexagon Agriculture, Agrium, aWhere, DuPont, FarmersEdge, Adapt-N, Farm Solutions

Source: Goldman Sachs Global Investment Research.

Precision fertilizer application and monitoring has the potential to meaningfully improve yield while reducing fertilizer consumption – factors that we believe can deliver up to $200 bn of value to farmers globally and contract the addressable market for fertilizer suppliers. Today, fertilizer application rates are nearly uniform within each individual farm. We estimate a 15-20% improvement in yield and a 4% reduction in fertilizer consumption of broad-based adoption of precision fertilizer application technology.

Providers throughout the value chain offer some combination of data (weather patterns, soil samples), software (weather modeling, nutrient run-off modeling, yield optimization), and hardware (variable rate applicators). According to Monsanto, with a fully integrated solution a farmer will be able to increase application rates in the part of the field where nitrogen run-off occurs, while reducing fertilizer consumption for up to 40% of overall farmland. The next generation of products equips a tractor with a sensor and a fertilizer application system, with automatic application rates around parts of the field where fertilizer absorption is low. Companies that are well positioned include Trimble, Monsanto, aWhere, Raven, FarmSolutions, FarmersEdge. Global fertilizer producers are at risk, including CF, Potash, Mosaic, Agrium.

Technology 1: Advanced weather and nitrogen retention modeling
Current providers of this solution use an initial soil sample, weather inputs, and geology to predict where fertilizer will flow once applied. As a result, the farmer can increase yield by

increasing application rates in the part of the field where nitrogen run-off occurs, while reducing fertilizer consumption for a major part of the field. The effect of this technology overlay is compounding; the algorithm becomes more accurate as more data is amassed, allowing the grower to be more prescriptive as the dataset grows. Companies with offerings in this field include Trimble, Monsanto, and aWhere.

Technology 2: Mobile sensor and application
Trimble has a product in the early stages of commercialization: Trimble dealers mount a sensor at the front of a tractor, and as the tractor drives, the sensor processes ground fertilizer levels and based on optimization algorithm signals fertilizer nozzles on the rear of the tractor for variable rate application.

Yield improvement and cost reduction opportunity is significant
The magnitude of yield improvement from commercial precision fertilizer products reported by industry participants ranges from 10% to 15%. The fertilizer consumption reduction is meaningful as well – Monsanto estimates a 10% reduction in fertilizer application on 40% of the farmers' field, equivalent to total reduction in consumption of 4%. Precision application of fertilizer in both the planting and mature stages of growing has reduced input costs, with a current payback period of 18-24 months according to Raven Industries. Based on these data points we calculate at up $200bn of value for farmers.

Key beneficiaries
Companies with offerings in this field include Trimble, Raven, Monsanto, Hexagon Agriculture, Agrium, aWhere, DuPont, FarmersEdge, Adapt-N, Farm Solutions.

Disrupted industries
Fertilizer producers could see a 4% reduction in total application rates. Impacted companies include CF Industries, Potash Corp, Mosaic, Agrium, Yara, ICL, Uralkali, CVR Partners.

GreenSeeker technology – real-time fertilizer application.

FIELD NOTES

The expert: We spoke with Darryl Mathews, senior vice president and sector head of Trimble's Agriculture, Forestry, Positioning Services and HarvestMark divisions.

The issue: Blanket application of fertilizer is expensive and generates waste – a more targeted solution would provide cost savings and minimize chemical runoff.

The solution: Trimble's GreenSeeker technology mounts to the front of a sprayer/spreader, providing a real-time readout of plant health. This data can be fed to a precision spraying operation at the rear of the rig, allowing for targeted nutrient application. The company notes that this technology is in the early adoption phase, but key benefits to the grower include (1) an up to date readout of plant health and (2) the ability to gather data irrespective of weather (night time operation is feasible).

Monsanto FieldView

FIELD NOTES

The expert: We spoke with Monsanto VP and CEO and President of Climate Mike Stern. The flagship FieldView line of products provide big data driven solutions to assist farmers in making proactive fertilizing decisions.

The issue: Big Data solutions have yet to be applied in scale with precision fertilizer – MON aims to provide an integrated and commercial solution.

The solution: Monstanto views precision agriculture as a subset of what they describe as the Digital Ag Platform. The development of this platform, based on data from millions of acres of test field data, will allow farmers to make fertilizer decisions based on back-tested data. Once an individual farmer's field is surveyed, Monsanto's proprietary dataset can be applied to the growing and will allow for a more prescriptive and tailored fertilizer recommendation.

Precision Planting:

$45bn addressable market, $145bn potential value-add

- Helps customize seed plantation to the requirements of each part of the field, generating 13% higher yield
- **Technology in use:** Multi-seed planters, variable-rate planting
- **Complementary technology:** Algorithmic field modeling, in-field sensors, data analysis & management
- **Major players:** AGCO, Case New Holland, Deere, Kinze, Trimble, Raven, Hexagon Agriculture, Great Plains Manufacturing

Precision planting allows farmers to customize seed that's planted to the requirements of each part of the field without losing productivity – a practice that our farmer feedback indicates can deliver 13% higher yield at only a nominally higher equipment cost. There are three technologies in play (1) variable rate seeding, planting a higher number of seeds in fertile parts of the field, (2) multi-hybrid planting – planting seeds with different genetics appropriate to each part of the field and (3) integrating field data to continue to improve the decisions of the hardware in the prior two points. Assuming the 13% yield benefit, we estimate $145 bn of value-added to farmers globally. Field monitoring and data analysis is a key complementor technology that could deliver stronger returns. Companies that are leading aggregators and enablers in this field include Deere, Raven, Trimble, Kinze, CNHI.

Multi-seed planters entering commercial production

Multi-seed planters offer farmers the ability to combine properties of different seeds in one planting. As an example, some types of corn seeds grow well in land with high levels of moisture while others grow well in dry areas. By planting two types of seeds – one that can easily grow in each level of moisture – allows the farmer to better match each patch of land to the optimal seed. Although there are many varieties of seed, farmers have noted that having only two types is necessary to see the yield improvement. Users of multi-seed planting have noted higher yields of 5-15 bushels/acres (about 3-8%) from matching up the right hybrids (please see the vignette on page 18).

The best offense is a good defense. Growers note that the optimal hybrid seed mix utilizes two seed types; an offensive and a defensive variety. These varieties have been developed to optimize yield in dry/wet or nutrient rich/barren areas of land respectively, pushing yield to the maximum level possible for each individual acre. Growers observe that though the seed placement technology and equipment come at a premium, the yearly yield improvement makes the investment worthwhile.

Variable rate planting

Variable rate planting involves planting more seeds in parts of the field more suitable to growing crops and using fewer seeds in less arable areas of the land. For example, a farmer may decide that – based on data regarding soil quality, access to water, and prior history of fungus – the optimal allocation of seeds is 70% in one area and 30% in another. The goal with variable rate planting is a more effective allocation of seeds rather than a reduction in the number of seeds purchased. Thus, it is currently a yield improvement rather than cost management technique, with farmers observing yield improvements of about 5-20% depending on the type of crop being grown.

Field modeling is a core complementor technology
As a result of developments in algorithmic field modeling techniques (coupled with physical soil sampling), large-scale farming operations are now more aware of the prevailing nutrient and moisture footprint across their fields. Armed with this knowledge, farmers can be more prescriptive in their seed placement.

A word on Seed technology
The global seed industry has seen two major technology shifts in the last 80 years. The first occurred in the 1930s when hybrid corn seed was commercialized allowing seed breeders to cross breed different parental lines of germplasm leading to improved inherent yields for the resulting hybrid seeds. While average corn yields showed no discernable gains in the 60 years prior to hybridization, in the next 60 years, average yields increased about 400%.

Then beginning in the mid-1990s, biotech seeds were introduced first providing herbicide resistance and later insect protection. As a consequence of these new traits, farmers were able to protect the ongoing gains delivered from germplasm development. Consequently, in part due to these yield-saving traits, average yields have climbed more than In 2015, according to the International Service for the Acquisition of Agri-biotech Applications, 18 million farmers from 28 countries planted 180m hectares of biotech crops and since the initial commercialization of biotech crops, an aggregate total of 2bn hectares have been planted.

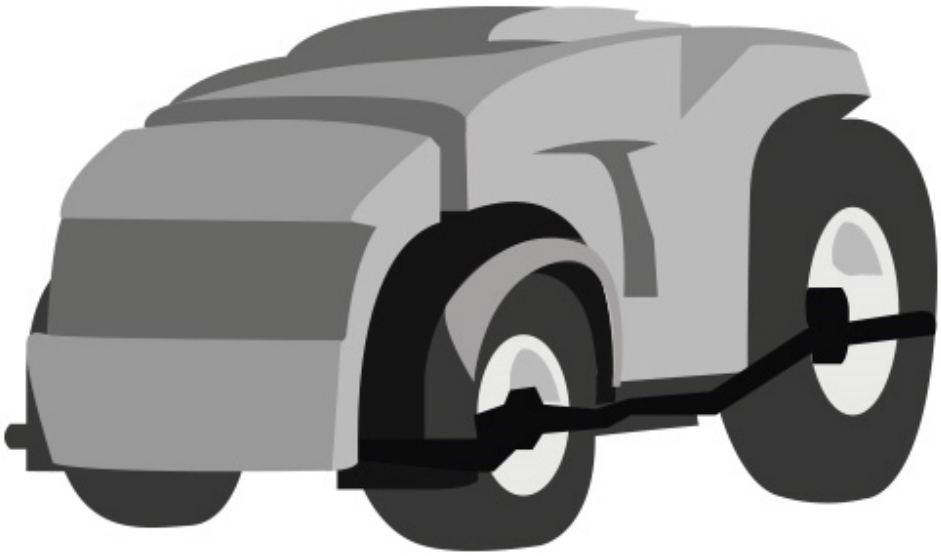
We expect future yield gains to continue from more efficient breeding techniques and additional biotech improvements. The use of high throughput screening, selective markers and advanced analytical screening should continue to drive annual yield gains of ~2 bushels/acre (1%). In addition, we believe the integration of historical data, agronomic conditions and predictive software will allow crop advisors to tailor the specific selection of hybrids at a field level for optimal yield potential. This can lead to input retailers providing a uniquely customized seed prescription for the farmer for hybrid selection, planting rates and timing across a farmer's plots.

Key beneficiaries
Current companies that offer the products or components include AGCO, Case New Holland, Deere, Kinze, Trimble, Raven, Hexagon Agriculture, Great Plains Manufacturing.

Compaction Reduction via Small Tractors:

$45bn addressable market, $145bn potential value-add

- Helps improve yield (10-15%) by reducing the amount of soil and roots crushed by heavy agriculture machinery
- **Complementary techniques:** Tracked equipment, deep-till plowing techniques, low inflation pressure tires
- **Upcoming technology:** Driverless Ag equipment (tractors, trailers, harvesters)
- **Major players:** MobilEye, LeddarTech, Bosch, Delphi, Continental, TRW, Quanergy



Source: Goldman Sachs Global Investment Research.

Compaction is caused by heavy equipment running over soil, damaging the soil structure – impacting the soil's ability to hold water, nutrients, and air necessary to support plant life. The size of tractors used for agriculture has increased steadily over the past 50+ years in order to reduce labor costs as well as harvest larger plots of land. As the power of agricultural machinery increases, so must the weight, with current machinery weighing in at over 20 tons in some cases. While these massive machines have significant scale, they come with the adverse side effect of damaging the soil. All in, industry estimates of the yield improvements derived from a reduction in compaction range from about 10-15%. Autonomous driving technology for agriculture equipment applications represents the most advanced solution to soil compaction.

Studies on the long term impact of compaction have shown that, starting under 10 tons, there is a noticeable reduction in yield loss. However, some researchers have noted that the ultimate goal would be to reduce machine weight to 5 tons while maintaining the same functionality and scale of the equipment. Doing so would likely require using equipment with a width of fewer than 10 feet and horsepower capabilities in the 60-70 range. Autonomous driving for agriculture equipment represents the most technologically advanced solution to soil compaction. The availability of driverless machines allows farmers to use smaller equipment with the same effectiveness and scale as the large, heavy equipment. For example, farmers operating the equipment could use a fleet of smaller (under 100 horsepower) tractors rather than one or two 600 horsepower machines for the same job. This reduction of gross vehicle weight would likely have a substantial

reduction of the pressure on the soil, helping improve yields while potentially reducing labor costs as well. If the industry shifts towards low horsepower products, Deere would have to deliver best in class integrated autonomous driving technology to maintain its dominant market position (50%+ share) in high horsepower applications.

Key beneficiaries
Major automotive suppliers of driverless technology are best positioned to benefit, if the industry moves in this direction. The list includes MobilEye, Bosch, Delphi, Conti, TRW, Quanergy.

Disrupted industries
Deere has the dominant market position (50%+ share) in high horsepower applications. An industry shift towards low horsepower products, would require Deere to deliver best in class integrated autonomous driving technology to maintain its position.

An interim step. A more gradual shift to tracked (as opposed to wheeled) equipment may be a more reasonable expectation for industry trends, as this layout spreads vehicle weight across a greater surface area. Additionally, deep-till plowing techniques can aerate soil and create additional pockets for root development.

A second proposal is the use of low inflation pressure tires. These tires would be attached the agricultural machinery currently in use, but would be designed to reduce the impact on the land from the rolling motion of the vehicle. Such tires have already come to market, with adoption levels rising.

An automotive viewpoint on driverless tractors

While autonomous driving cars have garnered a substantial amount of media attention, we believe that driverless ag equipment (tractors, trailers, harvesters) technology is another area where autonomous features could drive real financial benefits and support future adoption. As detailed in our Cars 2025 series, we believe autonomous vehicle commercial production could begin to ramp up as soon as 2025 in North America. In order to achieve this, we believe that a substantial sensor suite including radar, LIDAR, and cameras would be required to work in conjunction with embedded navigation as well as on-board processing, thereby adding a substantial amount of content onto future vehicles. In addition, we see scenarios where commercial use of autonomous driving vehicles geo-fenced in large cities/campuses could be introduced first perhaps by the end of the decade which is well ahead of everyday vehicles for consumer use.

Where driverless ag equipment could have tailwinds for adoption
We see opportunity for driverless tractors to proliferate due to a positive financial value proposition, enhanced aftermarket opportunities, and substantial overlap with existing autonomous car technology.

Strong financial value proposition – while a driverless tractor would likely come at a premium to standard ag equipment (we estimate a premium of approx. $2,700 for a car), we believe that the substantial ongoing financial benefits would provide a tailwind for adoption. At the most basic level, autonomous ag equipment would reduce labor costs as farmers would not need to employ as many drivers as they do currently. In addition, we believe that driverless equipment could result in efficiency gains for the farmer given increased precision in cutting and routing, as well as the potential for reduced losses as the equipment could clearly identify the edge of a crop so as to not damage neighboring crops that may require different equipment or be in a different stage of growth. While there is an opportunity in the long run for full autonomy of all vehicles, we believe that in the near-term, some drivers and manual control will still be needed, particularly for more complicated jobs.

Enhanced aftermarket opportunities – we believe that aftermarket solutions for cars are relatively difficult given the need to implement additional sensors in a visibly pleasing way as well and adding a considerable amount of additional processing power and communication networks within a car to enable autonomous driving. However, we believe that the aftermarket opportunity could be simpler for ag equipment and prove to be a key for adoption. The main driver of this is a reduced need for aesthetically pleasing and aerodynamic integration of the new technology which would reduce the complexity needed in designing the solution. In addition, ag equipment offer more space to work with than a car and in some cases, a simpler software platform to work on. An aftermarket solution could also allow for manual operation at times, which leads to increased operating flexibility. As a result, we believe that aftermarket solutions may be the preferred method of integration over purchasing fully autonomous equipment. For example, Autonomous Tractor Corporation which has been developing aftermarket solutions such as its AutoDrive product as well as fully autonomous tractor called the "Spirit."

Overlap with existing autonomous car technology – we believe that much of the efforts in developing autonomous car technology will lend itself to driverless tractors. We believe that the sensor suite for cars consisting of radar, LIDAR, and cameras will also be needed for successful driverless functionality for ag. Therefore, we can expect sensor suppliers such as Quanergy and Leddartech to draw on their expertise in car sensors to provide similar solutions for ag equipment. As mentioned earlier, we believe that the incremental development needed to design smaller and more aesthetically pleasing solutions is likely not needed given the different operating environment of tractors, trailers, and harvesters.

Areas where driverless equipment still face hurdles

While we see many opportunities for driverless tractors to gain traction, we do note several challenges remain; additional software complexity, liability concerns and farmer adoption.

Additional software complexity from a different operating environment – as we noted earlier, driverless ag equipment is likely going to utilize a similar sensor suite compared to cars and is likely to benefit from ongoing car sensor development. That said, we believe that incremental software will be needed given the different operating environment compared to cars. For example, driverless harvesters are more likely to experience situations with high dust and debris which may pose a challenge for certain sensors. In addition, driverless equipment must be able to identify crops and be able to identify obstacles in a field of tall crops. While we believe that these functions can be added over time through software, they do represent additional challenges to work through before full automation can be achieved.

Liability concerns could deter providers– similar with autonomous cars, safety is paramount to the success of driverless ag equipment. While operating in a field reduces the likelihood of an accident occurring, there are certainly possibilities where the tractor may go beyond the farmer's land and damage a neighbor's property or fail to identify structures within the owner's land and cause harm. In the event this occurs, the question of whether the owner or the equipment manufacturer bears the responsibility for the damages arises. As a result, we could see providers more reluctant to provide fully autonomous solutions to avoid the possibility of this additional burden.

Will farmers be receptive? – As with autonomous cars, we believe that a main determinant on the success of driverless ag equipment is the willingness for farmers to adopt the technology. The regulatory path is unclear. On the positive side, the tractor operates on private property, potentially limiting regulatory involvement. If regulatory supervision is required though, there could be a delay in adoption as the regulatory priority agenda will likely focus on the larger automotive applications. We believe that these substantial financial benefits could tip the scale in favor of farmer adoption.

Precision Spraying:

$15bn addressable market, $50bn potential value-add

- Helps improve yield (4%) by focusing pesticide application into areas where it's needed most.
- **Technology in use**: Data feeds from satellites & drones, weed-seeker technology
- **Major players:** Trimble, Raven, AGCO, Deere, CNH, Hexagon, Equipment Technologies

Precision spraying is based on varying the amount of pesticide application by area in order to reap the most significant benefits per unit of chemical applied. The metrics behind the cost savings and yield improvement vary, with related cost savings ranging from 4% from basic systems to up to 60% in Australia and South America. Yield improvements in the 4% range were estimated by experts in our discussions.

The current commercial precision spraying technology leverages regular data feeds from field monitoring systems – satellites and drones – to find areas that would benefit from in-season fungicide or other treatments. Our discussions with experts suggests estimate the potential yield improvement of a coordinated treatment plan at about 4%, while also meaningfully reducing crop production volatility.

The second major technological offering is branded WeedSeeker by Trimble – technology that takes stock of the field and identifies problem areas that contain weeds. Farmers using this information can more effectively apply pesticides by only targeting specific areas of the field in which weeds are present, leading to dramatic cost savings (up to 60% cited in Argentina, Brazil, and Australia).

Key beneficiaries
Current companies that offer commercial products include Trimble, Raven, AGCO, Deere, Case, Hexagon, Equipment Technologies.

Disrupted industries
We see pesticide/chemicals suppliers as susceptible to potential reductions in pesticide applications to a more targeted approach over time.

Ahead of the curve; S. America and Australia early in adopting Weed Seeker technology.

The expert: We spoke with Darryl Mathews, senior vice president and sector head of Trimble's Agriculture, Forestry, Positioning Services and HarvestMark divisions.

The issue: Blanket application of pesticide pollutes surrounding land (runoff) and wastes product. With considerations of environmental impact on the rise, targeted pesticide application is coming into focus.

The solution: Trimble's WeedSeeker technology allows for on-the-ground sensing of problem areas, targeting unwanted plant growth. The equipment is machine-mounted, allowing for more precise sensing and weed identification invisible to traditional satellite imaging. The system boasts up to a 60% pesticide cost reduction as compared to conventional methods.

S. America and Australia have lead adoption for this technology, largely because their growing cycle lacks a harsh winter that naturally kills unwanted growth. Penetration in the N. American market provides additional selling opportunity for Trimble.

Precision Irrigation:

$35bn addressable market,
$115bn potential value-add

- Uses sensors to apply the optimal amount of water to parts of the field generating the highest return from incremental irrigation.
- Improves yield by >10% while reducing water consumption by up to 50%
- **Technology in use:** Field-flooding, drip- and hybrid-irrigation & central-pivot irrigation
- **Major players:** Lindsay Corporation, T-L Irrigation, Trimble, Saturas Precision Irrigation, Common Sensor, Jain Irrigation, Rain-Tal Irrigation Systems

According to industry experts, precision irrigation has the potential to increase global crop yields by at least 10% – and in some areas by up to 80% – *while* reducing water consumption by up to 50%. The premise behind advanced irrigation is to use sensors to apply the optimal amount of water to parts of the field generating the highest return from incremental irrigation. However, the up-front capital costs for truly precision irrigation make implementation challenging compared to other precision ag technology that we've explored.

There are four irrigation options.

- **Field flooding** is the least efficient but the cheapest. It involves total field flooding, popular in rice and cranberry growing applications.
- **Central-pivot irrigation** installs a wheeled boom that sprinkles water several feet above the crop. The payback period for a central pivot system varies by crop. Taking corn as an example, a $7/bushel corn price can drive the payback period down to one year (though this is challenging in today's lower corn price environment).
- **Drip irrigation** is the most precise, requiring a drip feed to each plant. The system is costly, however, and difficult to install in large applications. Drip solutions are currently heavily used in vineyard farming.
- **Hybrid between central-pivot and drip.** A flexible drip line hangs from a central-pivot boom between crop rows and delivers irrigation directly to the plant, reducing evaporation and achieving up to 95% efficiency in water distribution.

Generally, mechanized irrigation (central pivot) is most efficient in row crop application, and is widely used as the preferred precision irrigation solution domestically.

Yield improvement varies – taking a look at the numbers:
Less than 15% of current US farmland is irrigated (representing 55mn acres), but the near-term addressable market is penetrated, at least based on current economics. As a result, irrigation manufacturers in the US are focused on opportunities for replacement and incremental technology sales (Precision Drip Irrigation, for example). The majority of system installations are for incremental application, moving from flood irrigation to central-pivot, which is estimated by central pivot providers to deliver a 10-15% yield increase. In addition to yield improvement, a precision irrigation operation lowers cost in several areas; both electricity and water costs are lower as the average volume pumped decreases dramatically

A true global opportunity. Over 90% of irrigation systems outside of the US are flood-based according to industry participants, providing ample opportunity for central-pivot conversion. Based on our discussions, the most significant opportunities are in the Middle East, Africa, and Central/South America.

Select manufacturers: Lindsay Corporation, T-L Irrigation, Trimble, Saturas Precision Irrigation, Common Sensor, Jain Irrigation, Rain-Tal Irrigation Systems.

Water consumption

The expert: We spoke with Dr. Susan Ustin of UC Davis, who specializes in remote sensing of environmental properties and landscape analysis utilizing optical, microwave, and thermal scanners; radiation interactions in plant canopies.

The issue: Drought affected areas (California farms and developing-world locations in particular) sharpen the focus on water usage in farming applications (over 80% of CA water goes to farm use).

The solution: In-field sensors can assist in identification of dry and saturated portions of the field, allowing farmers to make more targeted decisions related to water distribution.

Irrigation – a true doubling of higher yields

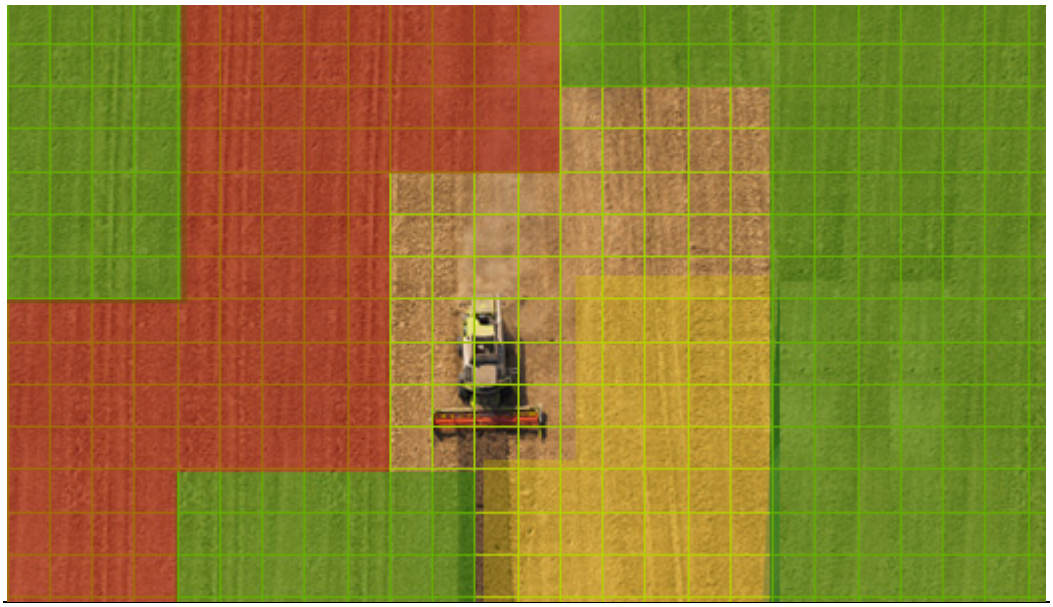
The expert: We spoke with T-L Irrigation, a provider of integrated irrigation technologies for farm application.

The issue: For arid regions, incremental improvement in moisture management is becoming increasingly important as the Ogallala Aquifer (a key reservoir for cornbelt farmers, spanning South Dakota to Texas) continues to drain.

The solution: T-L Irrigation's PMDI system presents a hybrid irrigation solution, combining center pivot and drip technology to cut evaporation and water waste, boasting a 10-15% yield improvement over traditional central pivot technology. Additionally, IL farmers using TL systems (traditionally a rain-fed crop state) to supplement intermittent dryness throughout the growing season saw a 40-60 bushel per acre improvement.

Field Monitoring

- A critical enabling technology, used in conjunction with spraying, fertilizer application and planting, to help a grower catch issues early
- **Technology in use:** Drones, satellites, weather tracking algorithms, and remote soil sensors
- **Major players:** Trimble, Hexagon Agriculture, aWhere, PrecisionHawk, Monarch, Raven



Source: Goldman Sachs Global Investment Research.

Field monitoring is a critical enabling technology used in conjunction with other precision farming technologies including spraying, fertilizer application, and planting. An integrated Field Monitoring solution allows a grower to catch issues early, be more prescriptive in fertilizer applications, and even change planting and harvesting dates during periods of high weather risk. Technologies in this field include satellites, drones, weather tracking algorithms, and remote soil sensors.

Remote moisture sensing is today's reality... Understanding the irrigation profile of a field is powerful information. Farmers armed with a moisture map of farmed land can direct irrigation only to dry areas, saving on cost. Additionally, growers can allocate water to perpetually dry areas to promote yield – famers utilizing this strategy see an average yield improvement of 3%.

...while the next frontier is Remote Nutrient Sensing. While current technology allows for full-field moisture sensing deployment, wireless and automated nutrient sensing is not offered on an institutional scale. Large fertilizer advisement companies have expressed interest in the technology once a comprehensive offering exists.

Drone fleets – greater scale is key to wider adoption. The advancement of Normalized Difference Vegetation Index (NDVI) imaging and drone flying technology has allowed for the development of field imaging via drone fleet. NDVI imaging allows for sensing of under-nourished and dry field segments, supplanting the need for in-field sensing. However, farmers are closely monitoring the cost of drone fleet ownership as current pricing makes this method of sensing uneconomical. Development of the drones as a

service business model could be key to wider adoption, as detailed in our Profiles in Innovation report on Drones.

Satellites offer scale benefits, but can be impacted by cloud cover. Satellite feeds can provide a regular time series of field development at a reasonable unit cost. aWhere, for example, offers weather predictive services based on decades of weather patterns. The additional information can help farmers decide planting timing and adjust seed types based on anticipated weather for the growing season.

Key beneficiaries
Companies with offerings in this field include Trimble, Hexagon, aWhere, PrecisionHawk, Monarch, Raven.

Drone fleets; its all about the software

The expert: We spoke with Maverick Drone Systems, maker of commercial drones for agricultural application.

The issue: As drone utilization increases, data collection and use comes into focus. Ease of integration across data platforms is currently quite fragmented, preventing cross comparison of data collected with different hardware.

The solution: Maverick's software provider (Sentera) integrates with several major farm management platforms (including MyJohnDeere), creating a central collection point for data and allowing for more powerful data analysis.

Some help from an eye in the sky

The expert: We spoke with aWhere, a provider of agricultural data that is utilizes proprietary techniques to blend networks of weather stations, ground radar, and satellites.

The issue: Weather patterns have an outsized effect on growing conditions, as they reallocate moisture and fertilizer nutrients in a field. Understanding the effect of weather patterns continues to be difficult given the number of variables involved.

The solution: aWhere captures over 1 billion points of data per day, and provides large and global datasets to growers, software developers, input providers, and financial institutions and other customers for macro to field level predictive insights. Using aWhere's dataset, agronomic and weather modeling, providers can develop a more prescriptive set of recommendations for growers to save on input costs, reduce risk, and increase yield. Traders and hedgers can assess global crop production risk every day through the growing season to inform risk mitigation and investment decisions.

Soil nutrient sensing networks

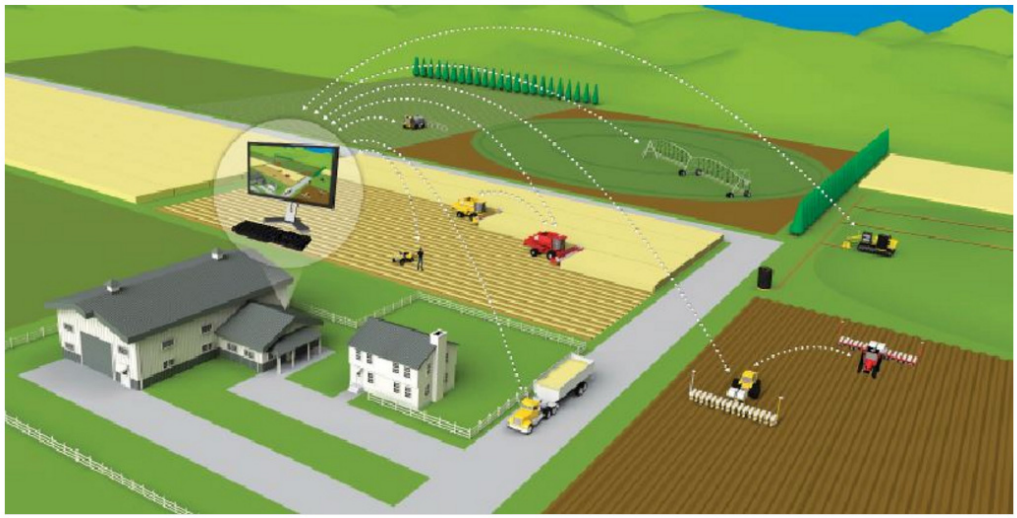
The expert: We spoke with Neal Horrom, Precision Ag Services Manager at Agrium.

The issue: Current soil sensor networks are primitive, with technology mostly aimed at gathering moisture level data.

The solution: Development of commercially-focused nutrient sensing networks to supplement in-field soil sampling will provide more accurate data to inform nutrient placement decisions. In addition to data gathering for purposes of field health management, Agrium sees the potential for soil-sensing networks to gather data for regulatory record keeping purposes as growing restrictions become more regimented.

Data Management

- Helps farmers make more informed decisions on every aspect of the growing cycle
- **Technology in use:** Software as a Service
- **Major players:** Trimble, Hexagon Agriculture, FarmersEdge, Crop Metrics, Deere, Monsanto, Ag Leader, SST Software, Topcon



Source: Trimble.

Big Data is here, and it's shaping the future of all large enterprises (farms are no exception). Yield, moisture, nutrient, and machine data can now be effectively measured. The burgeoning farm data management industry provides opportunity for farmers to make more informed decisions on every aspect of the growing cycle (for a price). In this field, farmers are spoiled for choice.

Most solutions are offered through a SaaS (software as a service) model, with an offering from Trimble priced at $1,500 for a 500 acre farm. Add-on services are available for additional cost, and include compliance, soil sampling, machinery, and imagery analysis (among other offerings). Today's Data Management software is compatible with major equipment, imagery, and sample providers via API which allows for diverse data sources to be aggregated into one platform. This creates a dashboard for growers, with interactive maps that can be overlaid with profitability, yield, fertilizer, and moisture data. This data dashboard can serve as the quantitative basis for virtually all data-driven decisions a farmer will make during and in preparation for the growing season.

Key beneficiaries

Current companies that offer the product include Trimble, Hexagon Agriculture, FarmersEdge, Crop Metrics, Deere, Ag Leader, SST Software, Topcon.

Big data in practice; using collected data to make an informed decision

The expert: We spoke with FarmersEdge Chief Technology Officer Kevin Grant.

The issue: Data integration from a wide range of sources.

The solution: The next frontier in yield improvement involves the formulation of large datasets to inform nutrient and water application decisions. FarmersEdge's product offering combines in-field sampling and data collection in conjunction with a software offering to provide yield improvement for the end user. This subscription-based model seeks to aggregate curated farmer data and provide tailored nutrient solutions for each customer.

Treating the 'Big Data' effect on Ag

The expert: We spoke with Monsanto VP and CEO and President of Climate Mike Stern. The flagship FieldView line of products provide big data driven solutions to assist farmers in making proactive fertilizing decisions.

The issue: Traditional field diagnostics are largely backward looking, and rely on analysis of physical samples (onerous across a 50+ field farm).

The solution: Monstanto's offering utilizes data from 30,000 acres of test farms across three states, informing an algorithm that delivers prescriptive/real-time farming solutions to maximize productivity. As sensor technology develops, Monsanto sees further opportunity to dispatch an in-field sensor fleet to sharpen the FieldView dataset.

Soil quality detection is only skin deep

The expert: We spoke with Dr. Anthony O'Geen (UC Davis). Dr. O'Geen's research involves Soil-landscape relationships, application of digital soil databases, soil survey, and management of soil physical properties.

The issue: Remote sensing attempts to predict soil characteristics from satellite imagery. To date, very few of those sensors go deep enough to predict soil quality in a meaningful way, requiring the development and retention of extensive (and expensive) datasets to focus fertilizer application.

The solution: Development of deep-soil sensing technology (with potential backing from the USDA and big-data focused technology companies) is in the early stages of development. The opportunity seems greatest for Midwestern farmers, where savings from precision fertilizing can have an outsized effect on farmer profitability.

Changes to the insurance landscape as technology sharpens underwriting

The expert: We spoke with Great American Insurance Group, and discussed their federally reinsured muti-peril crop insurance business.

The issue: Risk determinations must be made early in the year, 30-45 days before the crop is planted. At this stage Great American decides which part of its crop insurance it will keep vs. the part that moves to the government risk pool.

The solution: Technological developments in field diagnostics could provide an information edge for Great American, as drones and better satellite imaging provide a more accurate information set. Additionally, though the company offers few yield based products, the industry could be affected by certain harvesting equipment ownership.

Data collection a challenge; Raven has a solution.

The expert: We spoke with Steven Brazones of Raven Industries.

The issue: Though yield improvement from multi-hybrid planting is expected to be in the 5-10% range, data collection and farmer adoption rates act as headwinds.

The solution: Raven's product offering is focused on data collection, with a software platform that incorporates application program interface (API) to integrate with major OEM equipment. In addition to its software offering, Raven is focused on providing application sprayers for more accurate fertilizer and pesticide application.

The Phytobiome – Farming's next frontier

The expert: We spoke with Dr. Roch Gaussoin, Department Head of Agronomy and Horticulture at the University of Nebraska-Lincoln.

The issue: The Phytobiome of a farmer field remains unmapped and misunderstood (the Phytobiome refers to the biological activity of the soil).

The solution: The biological activity of soil affects nutrient uptake stress tolerance and plant development. Understanding these complex data requires massive computing power (on par with genome sequencing), and only recently has technology allowed for computation of this data. Once mapped, a greater understanding of the Phytobiome is viewed to be a large driver of increasing farmer yield.

Select companies with exposure

Exhibit 10: Precision Farming select company summary

Company name	Ticker	Value chain	Description
Precision Fertilizer			
adapt-N	Private	Components	Professional software to help agronomists optimize fertilizer recommendations
Agrium	AGU	Components	Fertilizer producer and distributor of general agriculture product
aWhere	Private	Components	Provider of ag data that blends networks of weather stations, ground radar, and satellites
CNH Industrial	CNHI	Aggregator	Designs and manufactures agricultural equipment that helps increase efficiency by reducing inputs
DuPont	DD	Components	Provides crop protection and other agricultural products and services
FarmersEdge	Private	Components	Provider of data collection and analysis that is integrated into a farm management platform
FarmSolutions	Private	Components	Provides aerial imaging and analysis to better control farm inputs
Hexagon Agriculture	HEXAb.ST	Components	Provider of information technologies that focus on productivity improvements
Monsanto	MON	Components	Develops and distributes seeds and agricultural products
Raven	RAVN	Components	Designs, manufactures, and services information management systems to support field decisions
Trimble	TRMB	Components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Precision Planting			
AGCO Corp.	AGCO	Aggregator	Manufacturer of agricultural machinery that improves planting efficiency
CNH Industrial	CNHI	Aggregator	Designs and manufactures equipment to support planting decisions
Deere	DE	Aggregator & components	Manufacturer of planting machinery and farm products
Great Plains Manufacturing	Private	Aggregator	Manufacturer of agricultural implements for tillage, seeding and planting
Hawkins Manufacturing	Private	Aggregator	Manufactures farm equipment
Hexagon Agriculture	HEXAb.ST	Components	Provider of information technologies solutions to improve input application decisions
KWS Saat	KWSG.DE	Components	Developer and distributer of seeds
Kinze	Private	Aggregator	Specialized farming equipment manufacturer
Raven	RAVN	Components	Designs and manufactures information management systems to improve planting decisions
Trimble	TRMB	Components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Compaction Reduction/Autonomous driving			
Autonomous Tractor Corp.	Private	Components	Creates and installs autonomous tractor systems
Bosch	Private	Components	Supplier of industrial & building technology
Continental AG	CONG.DE	Components	Provides engineering services
Delphi	DLPH	Aggregator	Vehicle component manufacturer and provider of electronic solutions
LeddarTech	Private	Components	Designs sensors for detection, location, and measurement
MobilEye	MBLY	Components	Supplies software and hardware for camera-based driver assistance systems
Quanergy	Private	Components	Developer of sensor technology for real-time mapping, object detection and tracking
TRW	Private	Aggregator	Creator and producer of active and passive safety technologies in vehicles
Kubota	6326.T	Aggregator	Manufacturer of planting machinery and farm products
Precision Spraying			
AGCO Corp.	AGCO	Aggregator	Manufacturer of agricultural machinery and sprayer equipment
CNH Industrial	CNHI	Aggregator	Designs and manufactures equipment that reduces inputs through better application control
Deere	DE	Aggregator	Manufacturer of sprayer parts and equipment
Equipment Technologies	Private	Components	Manufacturer and distributer of mobile drive sprayers
Hexagon Agriculture	HEXAb.ST	Components	Provider of information technologies that better control inputs
Trimble	TRMB	Components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Raven	RAVN	Components	Provides precision agriculture and data analytics to growers
Precision Irrigation			
Common Sensor	Private	Aggregator & components	Automatic irrigation that controls water supply
Jain Irrigation	JI.IN	Aggregator & components	Creates and sells various irrigation products
Lindsay Corporation	LNN	Aggregator & components	Provides infrastructure products and irrigation systems
Rain-Tal Ltd	Private	Aggregator & components	Manufacturer of water conserving irrigation products
Saturas Precision Irrigation	Private	Aggregator & components	Sensor system technology for crop irrigation
T&L Irrigation	Private	Aggregator & components	Manufactures equipment and consultation for irrigation needs
Trimble	TRMB	Aggregator & components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Field Monitoring			
AgDNA	Private	Components	Mobile app to help input application decisions
aWhere	Private	Components	Data collection and processing for weather and risk exposure
CropTrak	Private	Components	Mobile app for data interpretation and field monitoring
Hexagon Agriculture	HEXAb.ST	Components	Provider of information technologies that focus on productivity improvements
Monarch	Private	Components	Drone services to help manage crop health through improved resource utilization
PrecisionHawk	Private	Components	Provides drone-related services and aerial data products
Raven	RAVN	Components	Designs, manufactures, services and distributes information management systems to improve farm yields
Trimble	TRMB	Components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Data Management			
Ag Leader	Private	Components	Data management and technology to limit resource use and increase crop yield
Agrian	Private	Components	Software for data documentation
Crop Metrics	Private	Components	Develops and supplies management technology solutions for farm monitoring and resource conservation
Deere	DE	Aggregator & components	Manufacturer of information management products
FarmersEdge	Private	Aggregator & components	Data collection and analysis that is integrated into a farm management platform
Farmlogs	Private	Components	Mobile app for data logging
Hexagon Agriculture	HEXAb.ST	Aggregator & components	Provider of information technology solutions for measurement, positioning, and automating
SST Software	Private	Components	Support software for back-end infrastructure and services for custom applications
Topcon	7732.T	Components	Provides positioning technology and machine control products
Trimble	TRMB	Aggregator & components	Provides a suite of precision agriculture solutions/products to assist growers in maximizing yield
Monsanto	MON	Aggregator	MON's big data solution assists farmers in making proactive fertilizing decisions

Source: Goldman Sachs Global Investment Research.

Trimble (TRMB, CL Buy)

We see Trimble as well positioned to capture market share in an increasingly technological farming landscape. Precision farming revenues are minimal today, but if food supply is to keep up with demand Trimble is well positioned to benefit.

Trimble currently has a full suite of precision farm tools, ranging from necessary hardware (sensing, fertilizing, spraying, harvest, and irrigation equipment) and the relevant software. Trimble's FarmWorks software suite offers a range of services from mapping to accounting, and could serve as a future platform to integrate data as information collection continues to ramp in the farming space. We highlight the following specializations as a sampling of Trimble's core ag technologies:

- **Precision fertilizer**: Trimble's Field-IQ offering is a fertilization control system aimed at minimizing input cost to the grower. Using an integrated system of hardware (precision nozzles/boom adjusters and GreenSeeker technology) and software, Trimble is able to provide a more accurate fertilization system to the grower.
- **Precision Irrigation**: Trimble currently offers an Irrigate-IQ software product, aimed at maximizing the efficacy of central-pivot irrigation systems. Water flow, saturation, and cover can all be monitored on this central system. We estimate the TAM for irrigation to be ~$35bn by 2050 for a product line that's in the investment phase today.
- **Precision planting**: Trimble's Field-IQ crop input control system offers variable-rate seeding management and overlap reduction, key to any multi-hybrid seeding operation. The Precision Planting space is a $45 bn addressable market by 2050. The product is in the introductory phase today.

What's next for Trimble: Trimble's current technology suite puts the company in position to capitalize on continued integration of precision into farming. We view Data Management as one of the key areas of opportunity in the next decade, and the opportunity to be a dominant software and analytics provider provides opportunity for future profits.

Hexagon (HEXAb.ST)

Hexagon offers hardware as well as software platforms using technologies in electronics, measurement, positioning and automation in Precision Agriculture and Forestry. Hexagon's current portfolio includes a variety of hardware and software products used in fertilizing, seeding, navigation, and spraying. Key products include

- **Precision planting.** Hexagon's Ti5/Ti7 Agriculture Controller provides seed monitoring and planting.
- **Precision fertilizer application**. Hexagon's Automatic Section Controller helps manage spraying of fertilizer.
- **Information management and other software.** Hexagon offers software for planning and management at various stages of production and distribution of agriculture products.

Agrium (AGU/AGU.TO)

As the largest ag input distributor in the fragmented North American market, Agrium enjoys a unique direct relationship with growers. This puts it at the center of technological adoption by many growers, but also highlights some of the limitations and challenges faced in deploying many precision farming practices to growers.

Agrium's Retail division, Crop Production Services (CPS), has developed its Echelon Precision Ag platform to integrate a number of 3rd party data tools while also enabling closer engagement between CPS agronomists/crop advisors. Echelon focuses on three major priorities, precision data, services, and products. Notably, Echelon is built using 3rd party software and analytics (Agrian, IBM, adapt-N) and is able to integrate with 3rd party service providers (e.g. MON Climate Corp. and Deere).

Agrium intends to monetize its Echelon platform in three main ways:

- A direct service charge for technology/advisory work, soil sampling, or variable rate fertility
- A total solution charge, where AGU charges a per acre fee for total fertility, including soil sampling and variable rate blending.
- Greater product pull, as Agrium is able to leverage its analytics capability to demonstrate the value of higher-margin proprietary chemical and nutritional products to the grower.

As a result, Echelon is not (yet) a direct profit center for CPS, but rather an important way in which is maintains, if not strengthens, its direct engagement with growers, which remains CPS' critical competitive advantage.

AGCO Corp. (AGCO)

AGCO's precision farming platform, Fuse, focuses on open integration across a number of datasets. AGCO's offering is holistic, advertising end to end solutions from pre-crop planning to harvested storage. Fuse collects data from all aspects of the farming operation, and aggregates to a central platform, allowing for trend analysis and precision planting support from a central dashboard.

CNHI (CNHI/CNHI.MI)

CNHi delivers a range of precision farming solutions under the Advanced Farming Systems (AFS)/Precision Land Management (PLS) software technologies for its Case IH/New Holland brand. CNHi's precision farming platform focuses on real-time data collection, monitoring and analysis; and offers equipment support across various crop production phases, including seed planting, growing, harvesting and planning.

Deere (DE)

Deere has worked to build out a proprietary software platform, allowing for real-time monitoring of the Deere fleet from a central location and integration with other data sources. The Operations Center platform allows for a multitude of add-on functions, from fertilizer prescription creation to maintenance management for equipment in operation; integrated weather, yield, and spraying reports work together to make Deere's software offering a springboard for continued innovation.

Kubota (6326.T)

Kubota has been positioning itself as a leader in rice farming in Japan and Asia, developing multi solution to overcome obstacles in the industry such as aging farmers and declining working population in the farming industry. Since aging farmers are becoming one of the critical issues in the Japanese farming industry, Kubota has introduced power-assist suits for the elderly; the newest suit will weigh only 8kg(17lbs) to lift/load up to 200 cages.

Kubota is also building a proprietary Internet of Things software platform called "KSAS / Kubota Smart Agri System" and GPS controlled autonomous tractors (similar to CAT/Komatsu in mining equipment).

Monsanto (MON)

Given its leading competitive position in biotech seeds and breeding capabilities along with an expanding toolbox of data-based tools and collaborations, we believe Monsanto is at the forefront of the digital farming revolution. Given seed germplasm is the engine for yield potential, we expect Monsanto's role be key in driving the necessary gains in farmer productivity to expand global food supply.

At the heart of Monsanto's efforts to drive precision agriculture is its big-data platform under the Climate Corporation umbrella. Originally focused on weather-based algorithms that were commercialized as insurance products, Climate today integrates a powerful suite of tools to help farmers optimize their production planning and processes to maximize yields. By aggregating data that captures seed specifics with weather and soil measurement and predictive analytics along with pesticide and fertilizer applications, Monsanto provides customized recommendations for optimal yields.

The current suite of products includes:

- **Field View Prime**: This free offering is delivered to the farmer's mobile device. Field View Prime provides field level historical, current real-time and forecasted weather.
- **Field View Plus and Pro**: These premium offerings provide data integration to provide more powerful predictive capabilities. This includes integration with key machinery providers such as Deere, Agco, or Case to provide a robust real-time tool via wireless communication with the tractor, combine or planter to deliver digital representations right to the device in the farmer's cab.

  The Nitrogen Advisor app can help optimize amount and timing of fertilizer applications where Monsanto believes there is a $1b opportunity based on more than 50% of fields applying non-optimal rates. The Health Advisor can provide in-season and historical imagery to more effectively manage stressed areas and make field scouting more efficient. The Script Creator can use soil maps and data integration to provide customized zone-level seeding programs for rate and hybrid to maximize production.

Market progress and long-term goals for Field View: For 2016, Monsanto expects to invoice more than 12m acres of premium services and have coverage, along with the basic Field View offering, on more than 90m acres. Unlike its core seed business that is subject to regulatory hurdles and biological time constraints, scaling up digital ag can be substantially faster and offers exciting growth potential. Monsanto has partnered with 6 large US retailers (CHS, Agrium, Winfield Service, Helena, Wilbur Ellis, Growmark) covering most of the US and providing access to more than 3,000 advisor sellers.

For 2019, Monsanto targets 75m paid acres at $3.00-$4.50/ac and further penetration to the Canadian and Brazilia/n markets along with an expansion to wheat and soybean products. By 2025, Monsanto hopes to be on 300-400m acres worldwide.

Summary of select investments in Precision Farming technologies

Exhibit 11: Precedent transactions (venture capital included) in the precision agriculture space

Target	Acquirer	Size ($ in mn)	Description
Adaptive Symbiotic Technologies	Various (Crowdfunding platform)	$3.4	Adaptive Symbiotic Technologies (AST) has developed a line of biological seed treatments to increase yields by combating drought, temperature stress, and salty soils
CARANA Agribusiness	Various (Crowdfunding platform)	$1.3	An aquaculture and agriculture production business combining high value production, committed local buyers, international markets, and positive social impact.
SWIIM	Various (Crowdfunding platform)	$3.0	SWIIM gives farmers the ability to monetize their land's water rights, unlocking a new $150B market.
AGRI-TREND	Trimble	NM	Trimble acquired AGRI-TREND, the largest network of agricultural consultants in North America.
Precision Planting LLC	Deere & Company	NM	Deere acquired the Precision Planting LLC equipment business to enable near real-time connectivity between certain John Deere farm equipment and the Climate Field View platform.
IRON Solutions	Trimble	NM	Trimble acquired IRON Solutions market information, analytics-based intelligent, and a cloud-based enterprises system to improve dealer and producer productivity
The Climate Corporation	Monsanto	$930.0	Monsanto acquired The Climate Corporation to allow growers to make more informed decisions (regarding planting windows and irrigation schedules, for example) as they manage risk on the farm.
California Safe Soil	Various (Crowdfunding platform)	$5.9	California Safe Soil recycles fresh food waste from grocery stores into a high value fertilizer.
Edyn	Various (Crowdfunding platform)	$2.1	The Edyn smart garden system lets you know what's happening in your garden at all times
FiberStar Bio	Various (Crowdfunding platform)	$1.5	FiberStar Bio develops technologies that turn low-value food processing waste streams into highly functional, valuable, all-natural ingredients.
AgSmarts	Various (Crowdfunding platform)	$0.9	AgSmarts is the "Nest" for agriculture irrigation. Growers can expect to increase profits by over $63/acre compared to conventional irrigation management.
Tree Global	Various (Crowdfunding platform)	$0.5	Tree Global builds nurseries to serve large customers in emerging markets.
OnFarm	Various (Crowdfunding platform)	$0.8	A dashboard integrating data from nearly every major farm data provider.
Kuli Kuli	Various (Crowdfunding platform)	$0.4	Kuli Kuli's products are produced from moringa (a unique superfood) from women's growing cooperatives in West Africa
TerViva	Various (Crowdfunding platform)	$1.2	TerViva is developing a new class of agriculture crops that can be grown on sub-prime agriculture land with far fewer inputs
Home Town Farms	Various (Crowdfunding platform)	$0.5	Vertically integrated food growing and retailing system for suburban and city markets.
aWhere	Various (Crowdfunding platform)	$7.0	aWhere is a provider of agricultural data, that utilizes proprietary technologies to blend networks of weather stations, ground radar, and satellites
AGERpoint	Various (Crowdfunding platform)	$1.9	AGERpoint is a precision ag company focused on orchards and vineyards, and is focused on data acquisition, analysis, and translation.
Planet Labs	Various (Crowdfunding platform)	$123.0	Plant Labs offers a low cost satellite solution, operating a fleet of satellites and providing imagery services to customers
DJI	Various (Crowdfunding platform)	$75.0	DJI is a manufacturer of commercial and retail drones
3D Robotics	Various (Crowdfunding platform)	$64.0	3D is a manufacturer of commercial drones
Ehang	Various (Crowdfunding platform)	$42.0	Ehang is a manufacturer of commercial and retail drones
Parrot	Various (Crowdfunding platform)	$35.2	Parrot is a manufacturer of commercial and retail drones
Skycatch	Various (Crowdfunding platform)	$27.0	Skycatch develops drone control software for mapmaking
CyPhy Works	Various (Crowdfunding platform)	$24.5	CyPhy Works is a manufacturer of commercial and retail drones
Clearpath Robotics	Various (Crowdfunding platform)	$23.5	Clearpath Robotics is a manufacturer of commercial and retail robotics
Pulse Aerospace	Various (Crowdfunding platform)	$21.2	Pulse Aerospace manufactures helicopter Unmanned Aircraft Systems
Granular	Various (Crowdfunding platform)	$21.1	Granular makes farm management software, giving comprehensive crop assessment and yield sensitivity analysis based on in-season variables
Conservis	Various (Crowdfunding platform)	$17.7	Conservis develops workflow management software to assist farmers in making informed business decisions
Blue River Technology	Various (Crowdfunding platform)	$17.0	Blue River Technology manufactures next generation agricultural equipment, integrating precision agriculture into product design
Farmers Business Network	Various (Crowdfunding platform)	$15.0	Farmers Business Network is a data-sharing platform, aimed at providing objective information on seeds, fertility, and soils through aggregation of information sets
Swift Navigation	Various (Crowdfunding platform)	$11.0	Swift Navigation develops autonomous navigation capabilities
Mavrx	Various (Crowdfunding platform)	$10.0	Mavrx produces farm software to deliver actionable insights on crop cycle and workflow
CropX	Various (Crowdfunding platform)	$9.0	CropX offers soil sensing hardware for real time in-field monitoring, providing in-season data for growers
DroneDeploy	Various (Crowdfunding platform)	$9.0	DroneDeploy develops drone control software for mapmaking
Intermap Technologies	Various (Crowdfunding platform)	$8.8	Intermap Technologies is a global solutions provider aimed at solving spatial data challenges
Orbital Insight	Various (Crowdfunding platform)	$8.7	Orbital Insight provides a software solution for interpreting satellite imagery and data
Intelescope Solutions	Various (Crowdfunding platform)	$8.3	Intelescope Solutions utilizes global-scale satellite imagery data for the forestry industry

Source: Company reports, Agfunder

Disclosure Appendix

Reg AC

We, Jerry Revich, CFA, Patrick Archambault, CFA, Robert Koort, CFA, Adam Samuelson, Michael Nannizzi, Mohammed Moawalla, Andrew Bonin, Robert D. Boroujerdi, Hugo Scott-Gall, Jay Yang, Jesse Hulsing, Brooke Roach, Stephen Grambling, CFA, Noah Poponak, CFA, David Tamberrino, CFA, Yuichiro Isayama, Stefan Burgstaller, Lincoln Kong, CFA, Deepshikha Agarwal, Gautam Pillai, Christopher Evans, Ph.D and Ryan Berney, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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