

How would Google farm?

The race to feed 9 billion people through the Internet of Agriculture and analytics.



BY (l-r) ALEX THOMASSON, GABE SANTOS AND ATANU BASU

A solution to world hunger might be found on the streets of Mountain View, Calif., and Austin, Texas. We're talking about [Google's self-driving cars](#), now being test driven, and the technology behind them.

Although semi-autonomous farm equipment has existed for several years, the link between the tech giant and feeding the masses has more to do with sensors, data and analytics and less to do with just machines. In the decades to come, the intersection of these informational technologies will become increasingly crucial to feeding the world.

The need to rethink food production has never been more urgent. Anticipated

population gains in developing countries and shifting demographics, particularly the expansion of the middle class, provide the biggest clues to what is coming. World [population](#) is predicted to grow from 7 billion today to 9.6 billion by 2050 and plateau at around 11 billion in 2100. That's a lot more hungry mouths.

Clearly, the demand side of the equation is daunting; the supply side also looks problematic. Urbanization, road construction and potential climate effects reduce the amount of arable land available for farming. Taken together, those issues will require that food production per acre of land be doubled to meet the burgeoning demand by the end of this century.

Current agricultural technologies offer little hope for a solution. Growth in agricultural productivity is declining worldwide, according to the [U.S. Department of Agriculture](#). Growth in productivity of grains and oilseeds, for example, averaged 2.4 percent per year from 1970 to 1990. But between 1990 and 2010, productivity growth fell to 1.6 percent annually, and the downhill slide is continuing. By 2021, it's expected to be down to 1.5 percent.

Farmers in recent years have used new technologies in an attempt to increase crop yields while using fewer resources. But those technologies have been adopted piecemeal, resulting in less-than-desired outcomes. That's where Google comes in.

WHAT DOES GOOGLE HAVE TO DO WITH FARMING?

Google's big leap forward in the race to autonomous cars is its success at developing a *fully integrated system*. That system relies not only on sensors, but also on data – static and dynamic, and in many forms – along with algorithms from different scientific disciplines. If we are to meet the challenges of feeding an expanding global population, then adopting



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an integrated approach that takes into account advances in informational technologies and complementary scientific disciplines to improve crop productivity is essential.

Google's blueprint for transforming our mobility is predicated on sensors, data and software. Like a human driver, the computer-driven car is designed to detect the driver's location, understand what's happening around the driver, predict what might happen next, prescribe what to do, and then implement this prescription. At the same time, Google must design cars with the capability to navigate varied and complicated scenarios and obstacles, including pedestrians and cyclists.

Crop production operates under a similar system of varied field and plant

conditions. Farmers must tailor their practices to address the vast differences that can exist on the same farm across topography, soil type, fertility, moisture content, plant health, weeds, insects and diseases. New [precision agriculture](#) technologies that take advantage of guidance systems and sensors potentially allow farmers to customize their practices by the square meter rather than by the acre. These tools have led to some advances, but those improvements have been only incremental as they often focus on one factor at a time. Such point solutions increase efficiency but won't solve world hunger.

Nor can precision agriculture technologies alone be sufficient. A scientific understanding of the genetic structure of the plants growing in the field is also required. That scientific knowledge must be fully integrated with the precision agriculture technologies to predict how a plant will respond to certain inputs in its environment (soil, moisture, temperature) and its various stressors (nutrients, weeds, insects, diseases).

Making advancements in precision agriculture without accounting for plant genetics is akin to Google testing its self-driving cars on actual roads without paying attention to vehicle performance. For driverless cars to move from a science experiment to an accepted reality, they must not only function in actual traffic conditions on city streets and highways, but they must simultaneously

provide optimal performance in terms of efficiency, speed and comfort. The same premise applies to farming.

PRECISION AGRICULTURE POINT SOLUTIONS

In agriculture today, the main avenues for increasing productivity are optimizing farming practices through precision agriculture and accelerating crop improvements through plant breeding and genetic selection. While both of these avenues approach different aspects of agriculture – farming methods vs. the capabilities of the plants themselves – they are not being used together. Even so, they have a great deal of overlap in that they both rely on sensor information, analytics and data-driven action. The solution to doubling farm productivity must fuse the two.

How do we get there? Let's stroll down the two avenues and see how they might intersect.

OPTIMIZATION OF FARMING PRACTICES

Precision agriculture uses a comprehensive set of information technologies that rely on site-specific field information to vary production and management practices across the entire farm. The agriculture industry has been developing site-specific optimization techniques since GPS and satellite imagery have been available. Robots have recently been introduced for tasks like

cultivation and plant thinning in high-value crops. Unmanned aerial vehicles (drones) are now being used to gather images of crop fields. Some of these technologies enable the possibility of prescriptive solutions that can improve yields, build and maintain nutrients over time, and reduce costs.

Although some achievements have been made, further advances in precision agriculture have been limited because of the lack of adoption and clear-cut benefits. Farmers have avoided potential precision agriculture technologies because of the time it takes to learn how to use them, the difficulty in managing the changes, and most importantly, a lack of obvious return on investment.

Moreover, despite our tremendous data-collection capabilities, field and yield information is only valuable to farmers if it informs a management decision or agronomic practice. More sophisticated analytical tools that can synthesize all forms of data must be developed to enable the next step change in optimizing farming practices.

ACCELERATED CROP IMPROVEMENTS

Over the last century mechanization has increased farming efficiency, irrigation has provided precious water to crops, and more land has been brought into production. But perhaps the greatest productivity gains in agriculture over the

last several decades have come about through breeding.

Plant breeders grow small plots of different types of plants within a crop type. While genetic technologies have advanced tremendously in recent decades, it has long been known that the different plants within a crop type (genotypes) were different because of their genetic makeup. When plant breeders grow these plots they look for particular traits of interest (phenotypes) such as high yield and tolerance to drought, insects and diseases.

Crop improvements through breeding continue, but the pace of adopting those changes has been slowing. Fortunately, crop breeders and geneticists now have new capabilities that can advance the field. They can more scientifically select critical genes to bring about crops with physically measurable traits that confirm the plant has been improved. Known as phenotypes, these newly developed traits can bring on higher and faster yields, greater resistance to the numerous sources of stress in nature, and even new unique properties such as high levels of specific nutrients to reduce malnourishment in at-risk populations.

Genetic measurement techniques have become fast and inexpensive. But genetic improvement has been slowed by the small number of plant varieties that can be included in a study because

of the amount of manual labor involved in measuring phenotypic traits.

[High-throughput phenotyping](#) is a new field that capitalizes on recent technological advances. It uses sensors and automated delivery platforms, including robots and drones, to dramatically increase the number and the quality of phenotypic measurements that can be made. This allows many more varieties to be included in individual studies and provides a deeper pool for selecting appropriate genotypes.

FUSING FARMING PRACTICES WITH CROP KNOWLEDGE

Taken independently, precision agriculture and high-throughput phenotyping can provide sizable benefits. But how can these two technologies be merged to maximize agricultural production?

Precision agriculture technologies provide farmers with ways to exert some control over the environment at the individual plant level, such as through the regulation of soil moisture and nutrient content. But, historically, precision agriculture has lacked detailed knowledge of how plants will respond in a multitude of situations. Crop models are evolving, but they are imprecise. We now have the potential to understand plant and field conditions on a single-plant or square-meter basis and relate them to physiological responses that are based on detailed knowledge of plant genetics.

Together, precision agriculture and high-throughput phenotyping give us a fairly high level of control over the desired phenotypes of a particular crop, which means we potentially have a great deal of control over yield and plant stress responses in the field.

The genius of Google's driverless car lies in its comprehensive analysis of data, which is aimed at creating a safe and efficient environment for vehicle travel. Compared to other fields where analytics have begun to be applied, agriculture is ripe for this type of thinking. Like transportation, it tends to operate over large areas with a great deal of spatial and temporal variability. Agriculture faces tremendous variability in crop and field status from location to location, not to mention weather.

BEYOND POINT SOLUTIONS -- THE INTERNET OF AGRICULTURE

The technological backbone of Google's automation project is the Internet of Things, which involves equipping objects with sensors and software so they can collect and exchange data. According to a recent [report](#) from the McKinsey Global Institute, the Internet of Things offers a potential economic impact between \$4 trillion to \$11 trillion a year in 2025. Opportunities to tap into the Internet of Things abound in agriculture as a number of proximal sensors are already being implemented