Drones are used for monitoring rice crops at CIAT’s headquarters in Colombia.

Photo: Neil Palmer (CIAT)

Data-driven farming proves fertile ground for O.R.

How CGIAR and CIAT are helping to bridge the human capital divide and grow the digital revolution in the developing world’s agriculture industry.

By Julian Ramirez-Villegas, Daniel Jiménez and Robin Lougee

The data and digital revolution has reached the agricultural sector. The growing use of data collected via sensors [1], satellites, mobile phones and other novel technologies enables farms and farmers to produce more for less – less fertilizer, less water and less land. The revolution is happening in both developed and developing countries, but there’s a big gap between the two worlds.
Big data and artificial intelligence can help farmers make better, informed decisions regarding crop management as scientists develop models and subsequently forecasts.

Climate Change and Data-Driven Farming

Climate affects all aspects of farming. This includes productivity, the area for cultivation and the intensity of cropping. It affects the food and income available, and ultimately the livelihood of the farming households.

In the past, many farmers in developing countries relied on what happened in the preceding year to make decisions about their fields. In changing climates, that does not work. To be able to manage crops, farmers need to understand the effects of climate on their crops. Thus, they would need to have accurate and reliable climate and agricultural information.

Big data and artificial intelligence can help farmers make better, informed decisions regarding crop management as scientists develop models and subsequently forecasts that can suggest the best crop variety to grow and the best time to begin planting.

Catastrophe Aborted: The case of Rice Farmers in Colombia

Since 2013, researchers at the International Center for Tropical Agriculture, or CIAT, which leads the CGIAR Research Program on Climate Change, Agriculture and Food Security, or CCAFS, have been offering agro-climatic services to rice farmers in Colombia. They do this in collaboration with government institutions and the national rice grower association, Fedarroz.

An agro-climatic service offers specific information about agricultural conditions and climate in a systematic and sustained manner so farmers can make a decision about whether to plant, what to plant and when. The information is delivered in formats that farmers, field technicians and others that help farmers make choices about their farms can appreciate and access.

To provide the service, CIAT and CCAFS researchers perform big data analysis, use artificial intelligence and develop models as scientists and subsequently forecasts.

A Kenyan farmer uses a mobile phone in the field. Photo: Neil Palmer (CIAT)
Data-Driven Farming

To improve the accuracy of the forecasts and to expand the capabilities of agricultural models, massive investment in research is needed.

For instance, a recent forecast suggested that farmers in the municipality of Saldaña plant the Fedearroz 60 variety before the end of March. The researchers talked with and analyzed the forecasts with Fedearroz, which disseminated them to its members via regular meetings, monthly bulletins and a web-based platform [11].

The work has paid off. By following the forecast-driven recommendations to not plant during the first of two annual growing seasons in 2013, rice farmers saved themselves from losses in the amount of $3.6 million. This impact has led to recognition by the United Nations twice [12].

**Challenges and Opportunities Ahead**

Increasing the accuracy of prediction models is one key challenge in providing agro-climatic service and scaling this up globally. As per an analysis, suitable climate forecasts can be produced for 80 percent of the areas where CIAT and CCAFS work. Although the success rate is fairly high, the goal is to make the prediction more accurate, across all agricultural areas, to minimize the risks related to climate change. Also, the agricultural modeling does not integrate decision-making under uncertainty. That is, the models help identify the best options to maximize productivity, but not necessarily those that minimize investment risk.

To improve the accuracy of the forecasts and to expand the capabilities of agricultural models, massive investment in research is needed. It will also require collaboration with skilled experts in the operations research community.

Operations research has a long history of applications in food and agriculture. This may not be surprising considering the sector's importance. Agri-food is a $15 trillion industry representing 40 percent of global employment and 10 percent of global spending [13]. It has a massive economic, social and environmental footprint.

The first applied paper in the flagship journal of the fledgling Operations Research Society of America was “Operations Research in Agriculture” [14]. It appeared in the second issue published in 1953. (The content of the first issue was reserved for the vision and business of kicking off the new professional society, which would later become INFORMS). More recently, work across the spectrum of INFORMS media channels in agriculture was highlighted in a special volume of INFORMS’ Editor’s Cut [15].

Agriculture production is a system of systems that includes biological, chemical, environmental, physical and human systems. System thinking predilection that is prevalent in many areas of operations research is well-suited for collaborations in agriculture.

Operations research deals with the science of decision-making. Farmers are at heart business people who must make decisions in an industry setting unlike any other. There’s a good reason farming is known as “legalized gambling” and gave rise to the euphemism “betting the farm.” Decisions in outdoor agriculture involve biological material that depends on environmental conditions for survival. This means that while an auto manufacturer can assemble a car the same way whether the factory is in Mexico or Michigan, in farming “all ag is local.” So best practices in one geography don’t necessarily translate well to another, or even from year to year on the same farm.
Thinking about agriculture in traditional manufacturing terms may be useful in understanding some of the complexities. For example, the makespan of crops is a growing season measured in months, and in many geographies, there is only one growing season per year. Crop production is a sequential process with little opportunity for rework. Bare spots from un-germinated seed identified after planting has been completed are often scrap that can’t be recovered. There is no opportunity to replant if the germinated corn is too high because the “work-in-progress” would shade and compete with any new seed. One bad weather event can destroy the entire season’s production in a matter of minutes. With climate change, farmers are working in a factory environment that has never been seen before, let alone understood and optimized for real-time hyper-local operations. The analogies go on [16].

Availability of data has been a gating factor in the past, but the gate is starting to swing. The Global Open Data for Agriculture and Nutrition (GODAN) is one of 70 external partners of the CGIAR Big Data in Agriculture Platform. It seeks to make relevant data available, accessible and useable for unrestricted use worldwide [17]. At a GODAN event, the shortage of data scientists able to use the data being collected strongly emerged across discussions in the different working sessions [18].

The CGIAR Big Data in Agriculture Platform aims to increase the impact of agricultural development by embracing big data approaches to solve development problems faster, better and at greater scale than before. It recognizes that as the nature of agri-food system problems becomes more complex, the solutions require expertise across more disciplinary, geographic and institutional boundaries.

The platform is developing novel methodologies and innovative pilot projects across a global network for collaborators. Five initial “communities of practice” that welcome new members have been established to facilitate sharing of methodologies and knowledge. The communities are: 1) crop modeling, 2) socio-economic data, 3) ontologies, 4) data-driven agronomy and 5) geospatial data [19]. A prime opportunity to engage is at the next CGIAR Platform for Big Data in Agriculture convention on Oct. 1-5, 2018, in Nairobi, Kenya [20].

Bridging the human–capital divide to realize the potential of data-driven farming requires analytics and data science talent. Data alone is useless without the skills to distill actionable insights leading to better outcomes. This is fertile ground for operations research.

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1. https://www.nature.com/articles/544521a
3. https://www.nature.com/articles/d41586-018-02566-1
4. http://bigdata.cgiar.org/about
11. https://pronosticos.aclimatocolombia.org