The Next Agricultural Revolution?

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Summary
One of the 21st century's biggest challenges is devising the food systems to equitably, safely, and nutritiously feed the world's growing population without destroying the ecosystems on which we depend for life. However, solving this challenge is far more complicated than simply producing more food. For instance, enough food exists today to feed the world's population, yet there are almost 2 billion overweight/obese people, while another 800 million are undernourished. Meanwhile, agriculture causes significant environmental problems. For many experts, technology — and in particular, the development of Big Data analytics — will allow us to solve these problems by producing more nutritious food with less environmental impact. However, these technologies are not a panacea and, unless they are deployed carefully, they will fall short in addressing some of the world's most pressing food security problems. Consequently, we need comprehensive and holistic policy frameworks that support regional food systems, prioritize efficient food distribution, develop food literacy amongst consumers, boost production through science and technology, and also protect the environment.

Current realities
Today, the world faces a major problem: how can we safely feed the world's growing population without undermining the ecosystems on which we depend for life? Many experts argue that at the root of this problem is the need to produce 70% more food by 2050, and they warn that if our farmers fail in this task, the world will become more hungry, violent, and disease-ridden. However, solving the "global food crisis" and sustaining future generations is about much more than simply producing more food. Indeed, the United Nations estimates that there are approximately 2,800 calories available per person per day today, suggesting that we already produce enough food to meet our global needs. Nevertheless, due to inadequate distribution, poverty, and inequity, there are almost 2 billion overweight or obese people and almost 800 million undernourished.

Food waste is also one of the major issues our food system faces, as one-third of the food we produce currently is wasted. In the Global North, this waste typically occurs in households or at retailers. For instance, Metro Vancouver estimates that 80,000 potatoes, 30,000 eggs, and 70,000 cups of milk are thrown away every day in the Lower Mainland of British Columbia. In the Global South, a similar proportion of the food is wasted, although this waste generally arises due to spoilage before it arrives to market, as a result of inadequate storage, inefficient processing, or poor-quality infrastructure.

A third issue is that we do not produce enough of the right kinds of food to assure that everyone can enjoy a balanced diet. Although nutritionists recommend that we eat approximately eight servings of fruit or vegetables each day, U.N. data show that we only produce approximately three servings of fruit and vegetable per person per day on the planet. Meanwhile, nutritionists recommend that we limit ourselves to three servings of cereals and starches daily, but data suggest that there are approximately 14 servings of cereals and starches available for every man, woman, and child every day (note: this does not include the cereals produced for livestock or bioenergy). Similarly, we overproduce oils, fats, and sugars. This mismatch between what we produce and what we are recommended to consume for optimal health contributes to the rising burden of chronic disease associated with diet (see Figure 1).

Finally, there are the critical environmental issues such as the fact that: (i) up to 270,000 km²

per year are deforested or desertified as a result of agricultural expansion; (ii) livestock production contributes to the rise of antibiotic resistant bacteria; and (iii) food and farming systems contribute to about 30% of global greenhouse gas emissions. The global food crisis, therefore, is more about how we produce food, the environmental and social impact of food systems, distribution, and waste than it is about simply producing enough calories.

Scientific opportunities and challenges

Many argue that science and technology will solve the challenge of feeding the future. In many ways, there are huge scientific opportunities and, with emerging technologies, future farmers will be able to produce much more food on less land with fewer inputs, such as fertilizer or irrigation water. In particular, machine learning, cloud computing, and the ability to collect vast amounts of real-time data from farms will allow farmers to tailor inputs and management (e.g., fertilizer applications) far more precisely and with much greater efficiency.

For instance, satellite-guided tractors are able to collect harvest data on a meter-by-meter basis, and this information can be combined with high-resolution soil maps to allow farmers to divide fields into "management zones" and easily treat each zone differently. Smart tractors are now able to "learn" which parts of the field are more susceptible to drought (requiring drought-tolerant seeds and higher irrigation rates) versus what areas are unproductive and better set aside and reserved for pollinator habitat. The same sort of big data analytics and high-tech tools are changing the nature of livestock production as well. The dairy industry is at the vanguard of this transition with the "robotic milker" taking the place of human labor in many modern dairy barns. Under this system, each cow has a microchip and when they want to be milked, they enter the robotic milker, which is able to identify the cow and its life history. Robotic arms sterilize and attach to the udder and, while milking, the machine monitors the cow for health problems such as weight change, infections, or mastitis. This type of early diagnosis allows for a significant reduction in antibiotic use, thus reducing the potential that antibiotic resistant bacteria will emerge in our food system.

Taken together, these technologies suggest that we are at the beginning of a revolution in food and farming systems that will likely be as significant for the next generation as Green and Industrial Revolutions were for previous generations. However, where previous revolutions increased production by allowing more homogenous management systems to be applied across entire socioeconomic and ecological systems, the big data agricultural revolution will allow for much finer-grained management. Increasingly, robotic farming will be able to tailor inputs to the needs of specific plants and animals in real-time. This promises to shrink the environmental footprint of agriculture and allow us to produce much more food with much less impact.

Despite the possible benefits, however, such technologies are not a panacea and in many areas they will be extremely disruptive. For instance, many of these technologies require very little in terms of human labor. In countries like the U.S. or Canada, this will likely accelerate the ongoing decline of rural economies and communities. In countries of the Global South, many of which are still structurally dependent on agricultural labor, these issues are even more pressing since there may be few urban-based jobs to which people can move. For the small-scale farmer working on a hillside in a country like Malawi or Rwanda, satellite-guided tractors or genetically improved, high-productivity dairy semen are not as important as improving basic transportation infrastructure and improving access to markets. Finally, if these new technologies only allow for a small number of large-scale farmers to produce ever greater volumes of carbohydrates, fats, and oils, then these technologies will not have been deployed in such a way as to improve the food security needs of future generations.

Policy issues

Improve food distribution

- It is necessary to establish and reinforce partnerships between local and international development agencies that can work with farmers in less-affluent countries to establish the skills and the infrastructure to market farm products. This will help reduce poverty and ensure that food reaches those who need it most.
- It is also vital to build strategic grain reserves in famine-prone regions as a source of emergency food. This requires partnerships between nongovernmental organizations, national governments, and the World Food Program.

Sustainably intensify production

- Publicly funded research must bring scientists together with small-scale farmers in the Global South to develop low-cost and locally appropriate technologies as a means of boosting production effectively. Particular emphasis must be given to enhancing the productivity of "orphan crops" (e.g., productive and nutritious crops like millet or cassava that have not been the subject of widespread breeding programs).
- Public-private partnerships must focus on developing "big data" precision-agriculture technologies that will increase production while minimizing environmental impact.

Support local – regional food systems

- Local food systems will never feed all of us all of the time yet they represent a vital line of defense (or buffer) between consumers/producers and the vagaries of international commodity markets. Local food systems can also provide valuable ecosystem services and help educate consumers about the origins of their food. National/provincial policy can help local food systems by ensuring public institutions such as schools, universities, or hospitals purchase from local farmers.

Protect the environment through policy and regulation

- National governments should move away from production subsidies on crops like corn (maize) and focus instead on paying farmers for managing well-cared-for environments (e.g., payment for ecosystem services).
- Another way the environmental policy can help is through taxing pollution (or other "negative externalities") such as carbon emissions.

Engage the public

- None of these proposals will be possible unless people everywhere demand that food be put on the public policy agenda. Therefore, we need educational programs to increase food literacy and food awareness. This includes a better understanding of the politics of food as well as skills such as gardening and food preserving and ensuring the next generation has basic culinary skills.

References

Fraser, E., Legwegoh, A., Krishna, et al. (2016). "Biotechnology or organic? Extensive or intensive? Global or local? A critical review of potential pathways to resolve the global food crisis." *Trends in Food Science & Technology*. 48: 78-87.

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Figure 1

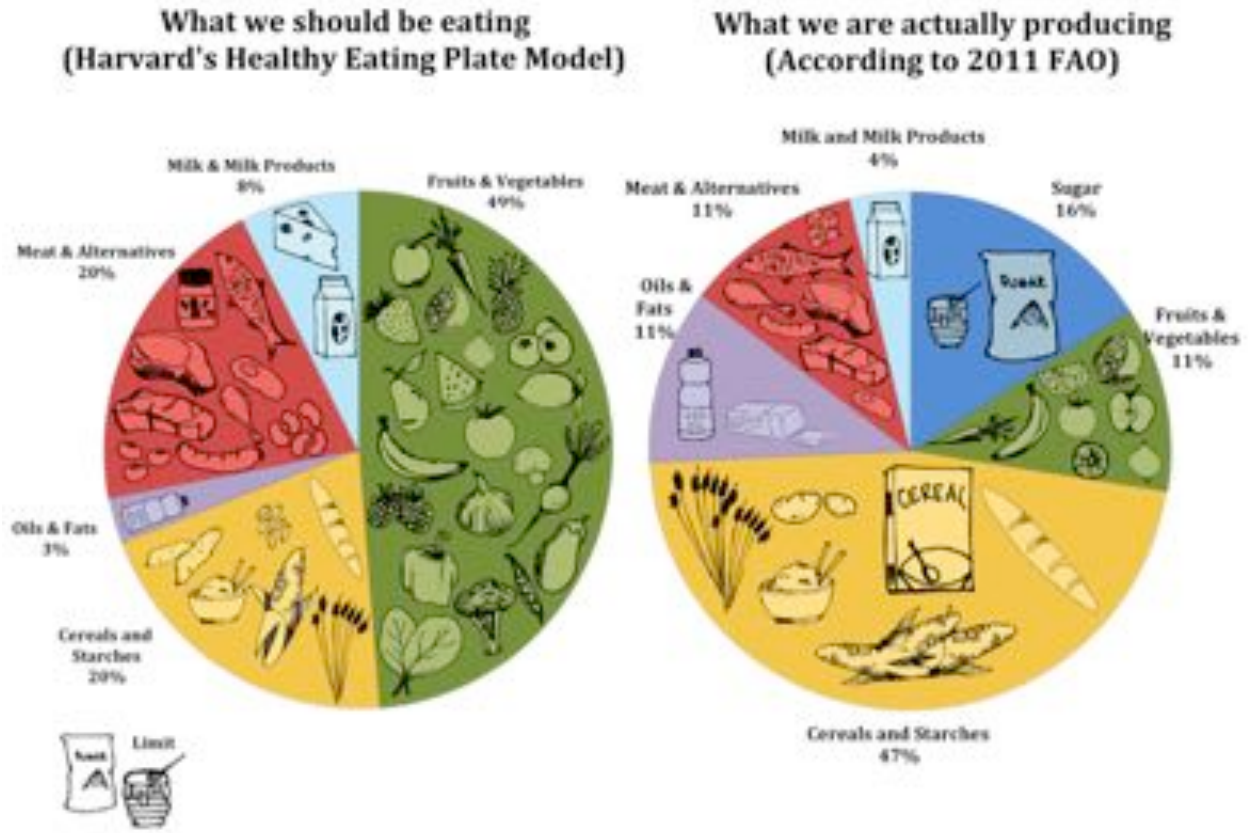

Figure 1. *A comparison of nutritional daily recommendations (left panel) and global food production data (right panel) measured in dietary servings. Note 1: when global production data are converted into servings, data show that there were about three servings of fruit and vegetable and 14 servings of cereals and starches available per capita per day in 2011 (the last year for which data were available). Note 2: production data on cereals and starches includes those produced for human consumption only and therefore do not include cereals and starches produced for livestock feed or bioenergy. Note 3: although the data displayed here are in dietary servings per person per day, similar trends are observed when data are displayed in total number of calories produced or total number of hectares devoted to each of these types of crops.*