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Viewpoint

Biotechnology or organic? Extensive or intensive? Global or local? A critical review of potential pathways to resolve the global food crisis

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ABSTRACT

While experts agree that poverty, population, energy prices, climate change, and socio-political dynamics undermine global food security, there is no agreement on effective strategies to meet this challenge. For example, some promote "high tech" solutions (e.g. biotechnology) designed to boost yield while others prefer local food systems. To better understand these debates, this article explores four perspectives from the literature: (1) technology to increase food production; (2) equitable food distribution; (3) policies to reduce pollution and waste; and (4) community action to promote sovereign food systems. The paper concludes with recommendations on how food scientists can navigate these controversies to help research and policy making.

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1. Introduction – the global food crisis

Many academics and policymakers interested in global food security are concerned that humanity faces a major crisis over the next generation (Foley et al. 2011; Godfray et al. 2010a). Population growth and economic inequality are shaping new global demands for food, while climate change, volatile energy prices, soil erosion, and water scarcity threaten to make food more difficult and more expensive to produce. Meanwhile, technological innovation offers the promise of boosting productivity and ameliorating some of these challenges. Because of these factors, many experts are worried that we face a "perfect storm" of problems; unless we use technology to increase food production, while at the same time decreasing agriculture's impact on the environment, the world may become hungrier, more violent, and more disease-ridden (Beddington, 2009).

But while there is a broad consensus that developing food systems capable of sustainably feeding at least 9 billion people represents a major challenge, there is no agreement as to the best strategies to meet this challenge. For instance, and as will be outlined in detail below, some argue that we need technology, and in particular enhanced biotechnologies, to boost yields and ensure the earth produces enough food for future generations (e.g. Cassman, Grassini, & van Wart, 2010; Fedoroff et al. 2010; Jaggard, Qi, & Ober, 2010).

However, many argue that poverty and a lack of political power are more important in terms of causing hunger and malnutrition than the ability of a region to produce food. In other words, the fact that some people lack that ability to demand food from the market is a larger determinant of food security than harvest or yield (e.g. Sen, 1981). Supporting these arguments are data that show there is

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enough food on the planet for everyone: after accounting for food waste and crops used for bioenergy, there are approximately 2850 dietary calories available on the planet per person per day (FAO, 2015a,b). Nevertheless, approximately 800 million go hungry (FAO, 2015a,b). Even if we assumed that food production remained constant, while our population grows to 9 billion, by 2050 there would still be 2200 dietary calories available per person per day, which is enough for us all to have adequate nutrition (Nb. the situation is the same if you examine calories, grams of protein, or grams of fats). In addition, at least 10% of global corn production that could be used for human consumption is used for bioenergy production (Graham-Rowe, 2011) and approximately 1/3 of the food currently produced globally is wasted before it is consumed (FAO, 2011). Overall, therefore, global data suggest that distributional problems are significant and these will not be rectified by simply increasing production. Finally, critics sometimes argue that the development of agricultural technologies, such as high-yielding seed varieties or other agri-inputs, typically benefit a small number of rich corporations and provide little in the way of meaningful progress towards reducing food insecurity (Tomlinson, 2013).

In light of these conflicting accounts and data, the purpose of this viewpoint article is to review the academic literature on topics relating to "solutions to the global food crisis". This is important because food scientists often find themselves inadvertently thrust into the heart of this acrimonious and volatile debate. For instance, in 2012 the UK government approved genetically modified (GM) wheat trials at Rothamsted Research. The scientists explained that their work is important for improving the sustainability of the food system: "Growing wheat has an environmental toll of extensive insecticide use to control aphid pests. The research, which is non-commercial, is investigating how to reduce that by getting the plants to repel aphids with a natural pheromone." (See more at: (Sense about Science, 2012)). But protestors disagreed, and one group called "Take Back Our Flour" wrote a series of letters to the *Guardian* newspaper where they declared that even doing research on GM may harm the integrity and sustainability of our food:

> Our vision is for an agro-ecology based farming involving using appropriate technology available to even the poorest farmers … [For] a food system that is not contaminated by GM or pesticides …. Empirical evidence shows that GM crops simply cannot co-exist with non-GM crops, so the choices we are making now have vital implications for future generations (Manchester Guardian, 2012).

Arguments over the most sustainable ways of feeding the world's population are not limited to disputes between environmental activists and bioengineers (Tscharntke et al. 2012). For instance, Badgley and Perfecto's (2007) article "Can organic agriculture feed the world?" concluded small farms that use crop rotation and avoid chemical inputs have the potential to address global food needs (See also: Badgley et al. 2007). Their article provoked a swift counter argument from Connor (2008) in a paper entitled: "Organic Agriculture Cannot Feed the World." Similarly, Seufert et al.'s (2012) meta-analysis in *Nature* found yields on organic farms were lower than those on conventional systems. This paper also launched a series of debates – both in the academy, and on social media – on the food production models best suited to meet global food security needs while protecting ecosystem services (Montenegro, Carlisle, Shattuck, & Kremen, 2012).

These illustrative debates – just two of many controversies related to the global food supply (i.e. food cloning, rBST, farmed salmon …) – show how researchers sometimes find themselves at the centre of polarized arguments that become entrenched around very distinctive technological, social, and ideological perspectives. In the hopes that a better understanding of these debates may be useful to scientists working on related topics, the purpose of this viewpoint review is to summarize some of the most prevalent themes in the food security literature. We aim to review the arguments for and against each position, and in doing so help food scientists understand some of the larger context of their research.[1]

2. Overview of key themes in the food security literature

Our reading of the literature suggests that there are at least four key pathways presented by scholars to solve "the global food crisis". These are:

1. Technology for Production. Arguments made under this theme stress the role of technological innovation to increase total production. Strategies proposed include using plant breeding and GM techniques to create disease or drought resistant varieties of plants, and bio-fortifying food crops.
2. Equity and Distribution. Arguments made in this theme stress the need for more equitable food distribution. Proposed strategies include poverty reduction, reducing global meat consumption, reducing the amount of grain used for bio-energy production, as well as changes to social welfare and trade regimes.
3. Local Food Sovereignty. Arguments made in this theme stress the need for communities to come together and promote more local and sovereign food systems. In wealthier countries these ideas are normally associated with "local food movements" while in the Global South – but increasingly in North America and Europe as well – these ideas are clustered around the notion of "food sovereignty".
4. Market Failures, Policy and Regulation. This theme stresses the need for policies and regulations to correct for perverse incentives that undermine the sustainability and security of our food systems. In particular, market failures and inappropriate subsidies result in pollution, waste, and excessive input, as well as leading to a proliferation of foods with large amounts of high-fructose corn syrup. Strategies proposed to correct market failures include incentives to reduce food waste, reducing distorting subsidies, and paying farmers for providing environmental benefits like carbon sequestration.

These themes are illustrated in Table 1 and the key arguments for/against each theme are summarized in the paragraphs below.

[1] *Methodological Note*. To explore debates on solutions to global food security, this viewpoint review article is based on the results of a systematic review of the scholarly literature. First, the research team created a database of scientific papers by querying the search engine "Web of Science" using the term "food security", restricting the range to articles published between 1993 and 2013. This generated 24,624 publications. The initial sample was narrowed down to only those articles that were published in highly cited international journals such as *Nature*, *Science*, *The Proceedings of the National Academy*, *The Philosophical Transactions of the Royal Society*, and subject-specific journals published by *Elsevier* and *Springer*. The research team systematically read through the sample, analysing the literature to identify recurrent themes until the point of theoretical saturation was reached. In this, we used an approach similar to that described by Braun and Clarke as a thematic content analysis (Braun & Clarke, 2006). Once we reached this point of theoretical saturation, eight senior scholars on the research team (two crop scientists, a food scientist, a global change modeller, a rural sociologist, and three human geographers who specialize on rural or food related topics) added supplementary readings and provided expert advice based on their disciplinary background. This led to a second round of critical reading where we reflected on, and confirmed the themes from, the first level of analysis. The critical reading process culminated in the development of a short (~1000 word) description of each theme, citing illustrative publications from the sample. These narratives were shared with the whole research team and edited in three rounds of revisions. The vast majority of the papers reviewed in this assessment were published between 1993 and 2013.

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