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FOOD SECURITY

Food systems transition and disruptive low carbon innovation: implications for a food security research agenda

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Abstract

There is a growing consensus that we are facing epochal challenges in global food security. Moreover, these challenges are multiple and complex. Meeting these challenges will involve nothing less than a wholesale socio-technical transition of the agri-food system. Optimizing the efficacy of the contribution of research to such a food security agenda will probably also need new institutional mechanisms and career structures to facilitate new kinds of collaborations and ongoing, longer-term projects. In short, the multiple challenges of food security demand a different political economy of research for effective intervention by science. In making this argument, the paper summarizes the major findings of a recent report regarding the potential impact of so-called 'disruptive' low-carbon innovations in China.

Key words: Agri-food system, ecology, food security, low carbon innovation.

Introduction

There is a growing consensus that we are facing epochal challenges in global food security. Moreover, these challenges are multiple and complex. First, food security itself is a multi-dimensional phenomenon, reflecting the overlapping and interacting questions of food access, availability, and utilization (Ericksen, 2008) and the cross-cutting dimensions of ecological sustainability, equity, and health (Lang *et al.*, 2009). Secondly, akin to the 'perfect storm' of converging challenges identified by Sir John Beddington (2009), food security in the 21st century must deal not only with the challenges of demography, changing diets with rising wages across the 'Global South' and declining rates of yield growth but also with an agrarian system in crisis (Lang, 2010; van der Ploeg, 2010) and the unpredictable impacts of climate change, together with its unprecedented time imperative. Moreover, efforts to tackle these already hugely challenging circumstances are being conditioned by the effects of the current global economic crisis, the most significant for 80 years, as well as by a geopolitical order that is seemingly in the midst of the flux that accompanies the 'rise and fall of great powers' (Kennedy, 1989).

Spelt out in these terms, it need hardly be said that the challenge of global food security (or even 'food sovereignty') will involve nothing less than a wholesale socio-technical transition of the agri-food system; one that incorporates and addresses the multiple ecological, socio-economic, and political dimensions and demands of the current conjuncture. Accordingly, it is clear that food security cannot be effectively tackled so long as it is conceived as a one-dimensional problem, for example, of increasing food production. Indeed, the messy interweaving of (*inter alia*) ecology, agriculture, and socio-economic and political conditions suggests that it may be much more productive to think of food security as a 'wicked problem' (Rittel, 1972; Hulme, 2009); one that has no clear solution nor even clearly demarcated and comprehensively understood dimensions, but demands constant, iterative, and long-term accommodation.

Research, including in botany and other agricultural sciences, has a crucial role to play in this momentous, epochal challenge of global food security. Acknowledging the multi-dimensional and wicked nature of the problem, however, also has significant implications for our (often inchoate) understanding of what precisely this role is. In particular, once it is recognized that food security incorporates messy socio-technical systems and their trajectories of change, it is immediately clear that research too must be understood as located *within* these systems. Two issues, in particular, then follow directly: first, redefining the nature of the *problem* clearly also redefines the types of research that are needed; secondly, and especially in the context of the current economic crisis, this, in turn, provides the basis to assess the policies of science funding regarding what science is funded, the rationale for levels and mechanisms of funding, with what expectations and which prospective beneficiaries and losers.

In this brief intervention, each of these two points will be considered in order to explore the implications of a systemic understanding of food security for a research agenda. The key lesson, it is argued, is that science has many crucial roles, but these are not limited to an increase in yield and, indeed, may be considerably different from the development of new hi-tech agricultural innovations, as is generally presumed by current research policy. Moreover, optimizing the efficacy of the contribution of research to a food security agenda will probably need new institutional mechanisms and career structures to facilitate new kinds of collaborations and ongoing, longer-term projects. In short, the multiple challenges of food security demand a different political economy of research for effective intervention by science. Scientists themselves, however, must mobilize for such changes, as a necessary if not sufficient condition, if they are to become realities.

The multiple challenges of a food security research agenda

Let us start with the current challenges of research funding. Readers of this journal will be well aware of the persistent downgrading of agricultural research, especially by public funding, across the developed world over the last few decades. In the UK, perhaps the most egregious example of this in recent years has been the evisceration of the world-leading Horticultural Research Institute at the University of Warwick (Driver, 2010). The UK, however, is by no means alone regarding the mismatch between the growing demands of the food security agenda upon agricultural research and a chronically under-funded public research infrastructure, including extension services. As food security has raced up the political agenda, a common, and thoroughly justified, refrain at the resulting recent conferences on food security has been the need to rectify this lack of support as a matter of urgency. Yet, in the UK and elsewhere, continuing attempts to deal with the global economic crisis through (controversial) programmes of fiscal austerity mean that such agricultural research is likely to face further large cuts; prompting 'brain drain' headlines in the UK (Vasagar and Shepherd, 2010).

Moreover, the present cuts are being justified in terms of a policy that has, for some decades, increasingly focused on the commercial gains available from research as the primary, if not exclusive, criterion for justifying public funding. Yet this demand upon science is not only illegitimately one-dimensional compared with the multiple gains from a strong research base, but is also based on a 'linear model' of innovation (from 'science' to 'innovation' to 'economic growth') that has been repeatedly shown to be, at best, a description of a small minority of innovations (e.g. in pharmaceutical biotechnology) and, at worst, completely fallacious (Kline and Rosenberg, 1986; Levin *et al.*, 1987).

The contribution of science to innovation is unpredictable and multiple, both in form and concrete impact, reflecting the fundamental uncertainty characteristic of all innovation. As such, it is often indirect (e.g. through education and/or through development of useful background knowledge), generally messy and iterative and even relatively unimportant in some industries. Moreover, this has been increasingly clear from a growing body of literature stretching back at least to the early 1970s (Gibbons and Johnston, 1974). Nevertheless, politicians have persistently, even obstinately, misunderstood the role of science in innovation, let alone in society more broadly, strengthening the political influence of the linear model almost as the inverse of its waning academic credibility.

Scientists themselves, however, need not make the same mistake. This is crucial because establishing an alternative research agenda compatible with the complex challenges of food security will be all the more difficult insofar as the current terms of debate about research funding are accepted. Unfortunately, however, in a bid to secure research funding in the current context, many scientists have been equally eager to embrace the linear model and to make often illusory promises regarding the direct benefit that their research will have on new technologies and commercial profit. Yet, fighting to prove the commercial relevance of (any given body of) science is a fool's game because, even in individual cases where this is successfully argued, the broader effects will be to cement the very misconception that undermines the levels and directions of funding that are actually needed. And politicians will only begin to take seriously an alternative conception of science, and why funding it is important, when there is a major lobby arguing for this alternative, i.e. when scientists themselves argue for it. In short, change in policy towards science funding is not likely, especially insofar as scientists do not challenge the criteria, but this demands of scientists that they themselves reappraise the role of science in innovation, including in the wicked problems of food security. As is often the case with such collective action and institutional reform, such re-evaluation may well not be (perceived to be) in scientists' *short-term* interests, demanding all the more commitment.

Secondly, then, as regards a systemic redefinition of the nature of the problem, the literature on socio-technical systems transition highlights the multi-actor (e.g. scientists in multiple locations and disciplines, entrepreneurs, stake-holders, government), multi-factor (e.g. laws, standards and customs, social relations and networks, technology and infrastructures), and multi-level ('micro' level individual niche innovation, 'macro' level landscape conditions from ecology, politics, economy etc… and, between them, meso-level regimes of innovation) challenge (Geels, 2004). In short, science is not the only important actor, or even (necessarily and in every case) the primary driving force of systems transition. Paradoxically, only by admitting as much can scientists begin to secure a more effective and reasonable assessment of the, still essential, role(s) of their research, and thereby break the cycle that sustains the linear model.

Indeed, as Elzen *et al.* (2004: 285) note:

'An important general pattern in transition processes … is that the course of [any given socio-technical systems] transition is shaped by the vicissitudes of the development of novelties in their early phases *when most actors in a system tend to see them as irrelevant*. … [This] requires users who deviate from the mainstream and who are prepared or interested in using a technology *with clear disadvantages* as well as investors who are willing to take considerable risks.'

Two particularly important points follow, as regards a food security research policy agenda. First, this systemic perspective directly challenges the presumption of the current high-input and 'productivist' model (itself in crisis; van der Ploeg, 2010) of agriculture and associated agricultural research that the *only* relevant research challenge is to increase crop yield through improvements (often proprietary) in high-technology solutions; a point amplified by the dependence of such high-input agriculture on limited and high-carbon fossil fuels set against the need to incorporate ecological criteria. Just as there are multiple possible alternative models of agricultural sustainability so too are there multiple possible research questions.

The complexity and messiness of systems transition entails at least the possibility that the most significant developments may well *not* depend on novel R&D-intensive high-technologies. Furthermore, a systemic perspective highlights the multiple *other* questions for optimizing scientific impact, regarding the irreducible socio-economic and political dimensions of diverse agri-food systems, absorptive capacity (the capacity of a region or organization to make effective use of an innovation), and the suitability of proposed innovations for different ecologies, economies, polities, and cultures. In the messy processes of systems transition, science impact is itself messy. Given this hugely expanded range of issues, however, it is clear that effective scientific research needs to be dispersed and engaged in ongoing, iterative and interdisciplinary collaborations (across the natural and social sciences) and with multiple stakeholders. In other words, science is arguably even *more* important (affecting arguments for its public funding), but tackling a different and broader range of problems.

Secondly, consideration of the nature of the problem from a systemic perspective makes it glaringly apparent that the challenge of food security is a global one, with multiple differing national or regional innovation systems all trying to get from where they currently are to some level of greater resilience and robustness. This has at least two crucial repercussions for a research policy agenda. First, it is clear that the individual and isolated efforts of no single country can possibly be enough to meet this challenge, so that international collaboration assumes heightened importance. Secondly, whether as a matter of basic global equity or as a pragmatic recognition of a changing geopolitical agenda (including of food), such international collaboration must extend beyond the existing established connections between OECD-based partners to include both developing countries facing the greater costs of climate change and the various new 'rising powers', such as China, India, and Brazil. International collaboration, however, always demands mutual benefit if it is to be successful. The strikingly different models of agriculture in these countries therefore also demands agricultural research into solutions that are appropriate not just to Western hi-tech and high-input agriculture (IAASTD, 2009; CTFCSA, 2010).

Disruptive low carbon innovation in China

An illustration of these points may be provided by considering low-carbon innovation in China, including in agriculture. This is an issue of key global significance, not just because of the large and growing carbon footprint of the Chinese economy as a whole, but also because China's spectacular social and economic growth represents a unique opportunity to develop and roll out low-carbon innovations. China's capacities in science and innovation are also improving rapidly. Following the financial crash of 2008, it is clear that China's growing geopolitical influence has entered a new phase, which will be a crucial determinant of global efforts to respond to climate change.

However, it must not be forgotten that China is still a developing country and caution is also needed not to exaggerate the current strength of China's science and innovation. The tendency to focus exclusively on expensive, hi-tech, low-carbon innovations, which would have to be imported and are thus seen to subtract from national economic growth rather than contributing to it, also tends to embed a perceived opposition between low-carbon innovation and socio-economic development. This, in turn, slows down the former, while it is clear that a low-carbon shift must attend to both. China cannot and must not be forced to choose between 'environment' and 'economy'.

In seeking to diminish this apparent contradiction, a recent report for the UK's National Endowment for Science, Technology, and the Arts (NESTA) has argued for the importance of one form of low-carbon innovation that offers considerable opportunities (both to China and elsewhere), but that is usually overlooked, namely 'disruptive innovation' (Tyfield *et al.*, 2010). Disruptive innovation challenges many of our common assumptions about innovation. It involves 'cheaper, easier-to-use alternatives to existing products or services, often produced by non-traditional players that target previously ignored customers' (Willis *et al.*, 2007) and/or use in novel contexts and combinations. Disruptive innovation is therefore likely to offer *lower* than cutting-edge functionality, according to established definitions, in the first instance but for different uses and to neglected users. It is thus primarily characterized by a social redefinition of existing technologies, as opposed to improvement of the technology along established trajectories. Given the potentially 'small beginnings' of a low-carbon systems transition, as discussed above, disruptive innovation could be a crucial element of such a seismic shift. This is especially so once it is acknowledged that the exceptionally tight time constraints for the necessary low-carbon transition mean that 'only the low-carbon technologies that are already known can make a significant contribution to meeting the 2050 targets' (Royal Academy of Engineering, 2010). But from the perspective of disruptive innovation, which makes use of just such established technologies, this maximization of climate impact need not be limited to current uses and familiar sectoral definitions of these technologies. Rather, disruptive innovation offers a potential route to substantial improvements in the societal impact of low-carbon technologies that is not dependent on their radical technological upgrade.

This argument becomes even more important in the case of China. This is not just because China's capacities for hi-tech, low-carbon innovation are not yet fully developed, as demonstrated by the continuing dominance of intellectual-property ownership of major low-carbon technologies by OECD-based companies (Lee *et al.*, 2009). But also because Chinese companies are already transforming global competition through their low-cost disruptive innovations (Zeng and Williamson, 2007), such as ZPMC's harbour cranes (52% of the world market), Zhongxing Medical's X-ray equipment (≈10% of the price of established rivals and with 50% of the Chinese market), Dawning's supercomputers (the second fastest in the world but at about one-third of the price per megaflop and with half the energy demand of the fastest), or CIMC's container ships (55% of global market share and six times the size of its nearest rival).

By focusing on low-cost products and services for the Chinese market, this also has the advantage of developing technologies that are appropriate not only for Chinese society but for other developing countries worldwide. With over 70% of total costs of abatement and hence low-carbon investment to 2050 likely to come from developing countries (Anderson, 2006), servicing this market would also be to focus on a major business opportunity, not merely to make a virtue of necessity by targeting secondary sources of demand.

Finally, but by no means least, building on the existing Chinese competitive strength of disruptive low-carbon innovation would also expedite a Chinese low-carbon systems transition, responding to the unprecedented time-scale. As the NESTA report details, five of the seven case studies profiled could have annual greenhouse gas emissions savings of 66 million tonnes CO_2e per year, while the other two will probably be major players in industries with total annual emissions savings of around 270 MtCO_2e. These are equivalent to the greenhouse gas emissions of 25 million and 100 million Chinese homes, respectively, or 4% and 16% of total Chinese emissions in 2006. Conversely, banking primarily on the improvement of hi-tech innovation capacities will incur substantial (and climatically consequential) delays, given the need to develop institutional, social, and cultural conditions that are hard to short-circuit (Table 1).

These case studies also include at least two examples that have direct implications for a food security research agenda. The most obvious example is the Lijiang Snow Mountain Organic Vegetable Cooperative, an NGO-established initiative that developed a full low-carbon system of agriculture. Based in the south-west province of Yunnan amongst poor farmers, success in this venture has relied on the introduction of new organizations and the tailoring of existing technologies in order to make the use of biogas digesters sufficiently attractive to the farmers to get them to take the risk of a major change in agricultural practices upon which their livelihood depends. By integrating the use of biogas digesters tailored to local requirements with the use of the resulting slurry as an organic fertilizer as well as the aggregation of farmers into a co-operative for improved access to finance and to wholesale markets, the farmers have been able to connect to lucrative markets for organic produce in China's major cities. As a result, significant reductions in greenhouse emissions have been achieved (of roughly 22 tCO_2e per household farm) together with significant rises in farmer's income (of approximately 12.5 times on average) (see Tyfield *et al.*, 2010).

Conclusions

What are the implications of the NESTA report for research policy and funding?

As argued above, the overall conclusion must be that a different political economy of science is needed to optimize the impact of research in the challenge of global food security. First, systems innovation does not always and necessarily need 'cutting-edge' science and hi-tech innovation, although such work undoubtedly remains essential as well. Secondly, it follows that the development and application of *existing* knowledge and in diverse and novel socio-ecological contexts is a crucial role for scientific research. For instance, research played a crucial role in the Lijiang Snow Mountain venture and could do so in expanding the model elsewhere. This, however, was a matter of devising and disseminating locally appropriate organic farming techniques, not developing radically new and high-technology solutions.

Thirdly, a research policy is needed that supports the long-term, iterative, and joint natural/social science projects that are needed to develop low-carbon food security innovations that address the multiple dimensions of these problems. Fourthly, such projects must be able to engage systematically with diverse users and *their* knowledge(s). Finally, international collaboration, such as the UK–China Sustainable Agriculture Innovation Network (SAIN), must be at the heart of this new political economy of research. All of these points, however, raise serious challenges for a model of science that primarily rewards publication in 'leading' journals that would be unlikely to find room for such research and/or research that promises (truthfully or not) immediate and direct commercial benefits.

We are currently confronted by a convergence of epochal changes that will impact on global food security. Yet such changes demand equally epochal transformation in science, its organization, funding, priorities, and connections. By

Table 1. The seven 'Chinese low-carbon game-changers'

The two case studies related to agriculture are in italics.

Disrupter	Description	Total potential savings each year (t CO_2)
Lüyuan	A major manufacturer of electric bicycles in a rapidly growing market of 120 million units.	130 000 000 (Total market)
Himin Group	Market leader in solar thermal water tanks, an industry that is, in turn, dominated by Chinese companies.	140 000 000 (Total market)
Sub-total for established companies		**270 000 000**
GEI Lijiang Snow Mountain Biogas Project	A project in south-west China to combine anaerobic biodigesters with organic agriculture that has depended on several institutional innovations to reach wholesale markets for such produce in distant major Chinese cities.	220 000
ISAW	A small, young company producing equipment that exploits 'psychrometric' principles to provide low-cost, relatively low-tech and low carbon alternatives to a range of processes that are usually extremely energy intensive, such as air-conditioning and solar desalination of salt water.	37 600 000
Pearl Hydrogen	A manufacturer of hydrogen fuel cells that is targeting markets for which there are existing uses, such as uninterrupted power supply (UPS) generators, small and specialized vehicles, and hand-held power sources, rather than targeting cars from the outset.	2 800
Shengchang Biomass	A producer of high-quality biomass pellets using agricultural residues that would otherwise be burnt on the field, as well as cheap combustion equipment designed to maximize combustion efficiency. The company also has a system to collect residues and distribute pellets within a radius of 20 km, thereby constructing a model of locally-sourced, renewable energy.	26 840 000
ZNHK (Sin-entech)	A producer of a low-cost but high efficiency water purification system that allows the high-temperature recycling of water in industrial processes. This reduces both energy that is normally wasted through cooling and reheating the water and the water demands of the industrial processes.	1 320 000
Sub-total for new ventures		**65 982 800**
Total		**335 982 800**

changing the debate about the funding of research at this crucial time and mobilizing around a clearly articulated (if, necessarily, developing) alternative conception of how science can and should contribute to systemic innovation, there is the opportunity to direct these changes in ways that benefit, rather than hinder, human and ecological flourishing. The concerted support of scientists themselves for such an alternative vision of research, however, will be crucial to realizing this potential.

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