STEPS centre

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Pathways Towards Sustainable Maize Production and Consumption in China: Prospects, Politics and Practices

Adrian Ely, Sam Geall and Yiching Song

Agri-food

LOW CARBON INNOVATION IN CHINA
中国低碳创新

China Low Carbon Report 4

Pathways Towards Sustainable Maize Production and Consumption in China: Prospects, Politics and Practices

China provides a stark and globally significant illustration of how changing patterns of food production and consumption are creating negative impacts on the environment. However, China's rapidly growing innovation capabilities and dynamic pattern of development also offer unique opportunities for system innovation towards more sustainable and resilient agri-food systems. This report discusses the technological, political and socio-cultural factors central to such system changes by exploring two contending (and not mutually-exclusive) pathways towards sustainable maize production and consumption: the first, with a focus on R&D-intensive transgenic technologies for agricultural intensification, such as phytase maize, the second, characterised by locally-driven innovation in organisational and management approaches, including agro-ecological and participatory research. These two pathways present different risks, benefits and implications for politics and practices, including changes in practices among farmers and consumers.

About the Authors

Adrian Ely is a Senior Lecturer at SPRU, University of Sussex, deputy director and head of impact and engagement at the STEPS Centre. He has worked on agricultural biotechnology regulation in China and is currently investigating the ethical challenges associated with biotechnology research collaborations between UK and Asian scientists.

Sam Geall is Research Fellow at the Science Policy Research Unit (SPRU) at University of Sussex and Executive Editor of chinadialogue.net. His research focuses on environmental governance, media and civil society in China.

Yiching Song is a senior research fellow in the Centre for Chinese Agricultural Policy (CCAP), Chinese Academy of Science (CAS). She leads a series of sustainable agriculture and farmer cooperative projects in China.

About China Low Carbon Reports

The project 'Low Carbon Innovation in China: Prospects, Politics and Practice' is led from Lancaster University and is a collaboration between British and Chinese researchers to investigate different models of innovation and their potential role in low carbon transitions. The China Low Carbon Reports detail the project's activities and findings in order to inform research and policy at national and international levels. Further information on this STEPS Centre affiliate project is available on the website **http://steps-centre.org/project/low-carbon-china/**

Follow us on Twitter: @Lowcarbonchina

About the STEPS Centre

The STEPS Centre (Social, Technological and Environmental Pathways to Sustainability) is an interdisciplinary global research and policy engagement hub that unites development studies with science and technology studies. Our pathways approach aims to link new theory with practical solutions that create better livelihoods, health and social justice for poor and marginalised people. The STEPS Centre is based at the Institute of Development Studies and SPRU (Science Policy Research Unit) at the University of Sussex, with partners in Africa, Asia and Latin America.

www.steps-centre.org

Follow us on Twitter @stepscentre

For more STEPS Centre publications visit:

www.steps-centre.org/publications

Papers in the Series:

69 Low-Carbon Innovation in China: Prospects, Politics and Practices

70 Pathways Towards Renewable Energy in China: Prospects, Politics and Practices

71 Low Carbon Innovation in Chinese Urban Mobility: Prospects, Politics and Practices

72 Pathways Towards Sustainable Maize Production and Consumption in China: Prospects, Politics and Practices

This is one of a series of Working Papers from the STEPS Centre www.steps-centre.org.

ISBN 978-1-78118-200-0

Pathways Towards Sustainable Maize Production and Consumption in China: Prospects, Politics and Practices

Adrian Ely, Sam Geall and Yiching Song

STEPS Working Paper 72

Correct citation: Ely, A., Geall, S. and Song. Y. (2014) *Pathways Towards Sustainable Maize Production and Consumption in China: Prospects, Politics and Practices,* STEPS Working Paper 72, Brighton: STEPS Centre

First published in 2014

ISBN: 978-1-78118-200-0

For further information please contact: STEPS Centre, University of Sussex, Brighton BN1 9RE
Tel: +44 (0) 1273915673; Email: steps-centre@ids.ac.uk; web: www.steps-centre.org

Contents

Figures

Acronymns

BPDVI	Breed-Produce-Distribute Vertically Integrated
Bt	Bacillus thuringiensis
CSA	Community Supported Agriculture
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the U N Statistics Division
FYP	Five-Year Plan
GAIN	Global Agricultural Information Network
GDP	Gross Domestic Product
GM	Genetically Modified
IP	Intellectual Properties
MEP	Ministry of Environmental Protection
MOA	Ministry of Agriculture
MOST	Ministry of Science and Technology
NDRC	[China] National Development and Reform Commission
NGO	Non-Governmental Organisations
PCD	Partnership for Community Development
PEAC	Pesticides Eco-Alternatives Center
PLA	People's Liberation Army
PV	Photovoltaic
PX	Paraxylene
RRM	Rural Reconstruction Movement
SOIS	Sustainability-Oriented Innovation Systems
US	United States
WTO	World Trade Organization

Abstract

This is one of a series of four reports outlining the STEPS-Centre affiliate project 'Low Carbon Innovation in China: Prospects, Politics and Practice', led from Lancaster University. It provides an introduction to the 'food and agriculture' work package of the project, reviewing the relevant literature around sustainable food and agriculture in China and describing the project's research approach and potential contribution to knowledge in this area.

China provides a stark and globally significant illustration of how changing patterns of food production and consumption (especially increased intake of animal protein) are creating negative impacts on biodiversity, greenhouse gases, nitrogen and phosphorous cycles and the use of freshwater. However, China's rapidly growing innovation capabilities and dynamic pattern of development offer a unique opportunity for system innovation towards more sustainable and resilient agri-food systems. This paper discusses the technological, political and socio-cultural factors central to such system changes, with a focus on maize as a core case study. In particular it presents two contending (and not mutually-exclusive) pathways towards sustainable maize production and consumption, one characterised by a focus on Research and Development-intensive (R&D) (including transgenic) technologies for agricultural intensification, and one characterised by locally-driven innovation in organisational and management approaches.

The focus on an example of R&D-intensive, intellectual properties driven approaches involves new transgenic products, such as phytase maize, which claim environmental benefits but, due to political controversy, are yet to be approved for cultivation. Alternative approaches such as improved management practices, supply chain innovation, agro-ecological and participatory research, present different risks, benefits and implications for politics and practices (including changes in practices amongst farmers and consumers). This paper outlines our approach to studying these two potential pathways as part of the wider project.

Introduction

Studying the extent and nature of low-carbon transitions in China could help us to understand better the socio-political implications of low-carbon innovation and offer new insights to innovation studies and other disciplines working on these challenges. This paper takes low-carbon innovation in agri-food systems as its sector of inquiry, introducing two case studies from China, in order to understand how different models of low-carbon innovation are supported and constrained by political debates in the country's changing policy-making environment, as well as how they relate to changing practices among various groups of producers and consumers. The case studies are:

- the centrally-supported development of genetically modified phytase maize as a potential component of intensive agri-food (including livestock) systems; and
- the emergence of agro-ecological and low external input sustainable approaches to the production and consumption of maize and associated agricultural products.

The paper provides an overview of the broader challenge of low carbon innovation and transition in China within which these case studies are situated. It also provides a justification for, and an introduction to, the case studies and their linkages within the context of China's agricultural innovation system. In each of the cases, it adopts the core areas of inquiry in a new research project (2013-2016) entitled 'Low Carbon Innovation in China: Prospects, Politics and Practice'.

These two agri-food case studies are not only linked by maize, a key staple Chinese food and feed grain with a long history – a history that echoes other countries where maize is economically and nutritionally significant, particularly the United States – but also by the changing dietary practices in contemporary China. This radically altered food system not only has climate impacts but also requires innovation to address some of its other key environmental and social challenges, including food safety, food security and food sovereignty. The paper examines each of the two case studies with reference to their prospects for contributing to a low carbon transition, the politics surrounding their possible contribution and the influences on, and the implications in terms of practice associated with, such a transition.

From the perspective of policymakers and scientists, innovation in Chinese agriculture has principally occurred in seeds, fertilisers (and other inputs) and livestock technologies. However, there are other forms of innovation in Chinese agri-food systems worth considering, many in response to consumers' changing preferences. These include efforts such as 'green food' labeling schemes, agro-ecological food delivery projects, community-supported farms or social movements around vegetarianism and other dietary practices. Therefore, this paper regards innovation, not as manifested in any particular technology or aspect of agriculture, but at a system level as it pertains to a low-carbon transition in China, and particularly in the context of changing dietary practices – practices that are socio-politically embedded – towards more meat-based diets. Thus, efficiency gains through innovation in livestock systems, for example, are not only considered on their own terms, but also in light of their role in contributing to innovations for sustainability at the level of practices, policies, food supply chains and broader sociotechnical transitions towards a low-carbon society.

1. The challenge of a global green transition

The Intergovernmental Panel on Climate Change (IPCC 2013: 19) recently concluded: '[…] limiting climate change will require substantial and sustained reductions of greenhouse gas emissions'. At the same time, earth systems' scientists have proposed broader 'planetary boundaries' on sustainable development, arguing that interacting anthropogenic changes to nitrogen and phosphorous cycles, freshwater use, biodiversity and land-use change, among others, threaten to bring unpredictable turbulence and tipping points, undermining the patterns of human development seen over the past 10,000 years (Rockström *et al.* 2009). It is now recognised that transformative innovation of many different kinds is required to bring patterns of global development within the 'safe operating space' determined by these planetary boundaries in a way that simultaneously addresses poverty alleviation and social-justice imperatives (Leach *et al*. 2012).

Scholars within innovation studies have been focussed on understanding these kinds of challenges for at least a generation. While earlier work presupposed inevitable trade-offs between economic growth and sustainability (Meadows *et al*. 1972), others (Cole *et al*. 1973) questioned these ideas, pointing towards the potential for new technologies to stretch environmental limits and transform the nature of growth itself. In the 1990s, there was a move towards understanding conditions under which to reconcile environmental performance with economic competitiveness, at the levels of both businesses and national economies (Porter and van der Linde 1995). At the same time, calls emerged for new models of innovation with a 'green techno-economic paradigm' (Freeman 1996) as a space began to open for the integration of industrial and environmental policies. Western European nations started to invest in energy-efficient and low-carbon electricity generation technologies, and eco-innovation assumed a place in the industrial strategies of many states.

Scholars and practitioners also began increasingly to recognise the role of the state in modifying both supply and demand (to be weakened not strengthened) sides of the eco-innovation system (Rennings 2000). Investment in high-risk or uncertain research and development, including in green sectors like wind and solar energy, became identified as an important role of an 'entrepreneurial state' (Mazzucato 2013). The shaping of regulations and markets to build demand for new-to-world innovations (Beise 2004) and thus produce 'lead markets' for low carbon innovations (Quitzow *et al*. 2014) has also been highlighted, whilst others have pointed towards wider governance considerations in generating sustainability and competitiveness at the level of national economies (Esty and Porter 2001). The idea of sustainability-oriented innovation systems (SOIS) has also emerged, with authors pointing to the governance challenges involved in managing disruptive green transformations in which incumbent interests are challenged (Altenberg and Pegels 2012). Reconfigurations challenging existing power structures are evident from a broad base of historical research that has provided frameworks and case studies analysing socio-technical transitions, drawing on evolutionary economics to analyse the interaction between technologies and institutions in systemic change (Elzen *et al*. 2004). SOIS scholars point to the likelihood of divergences in national and regional technological and development trajectories on the basis not only of resource endowments and capabilities, but also political differences (Altenberg and Pegels 2012).

Other scholars writing on the governance of social, technological and environmental changes have pointed to the key roles that different forms of knowledge and narratives play in framing, enabling and reinforcing particular pathways of change (Leach *et al*. 2010). Dominant narratives can serve to constrain people's understanding of sustainability challenges, leading to policies that shape directions of social and technical change in ways that, whilst addressing some policy objectives, may undermine other more marginalised and locally-applicable pathways to low carbon development (Byrne *et al*. 2011). While comparative studies of the politics surrounding contemporary transition processes have been conducted in Europe (Lockwood 2013, Smith *et al*. 2014), similar studies in other parts of the world (including China) are notably lacking. By studying two distinct innovation models and potential pathways to more sustainable agri-food systems, our research aims to be able to interrogate these kinds of questions and to begin to fill this research gap.

2. Issues facing China's green transition

Emerging Asian economies such as China and India have over the past decade assumed a greater significance in global innovation systems, raising further opportunities for eco-innovation (Ely and Scoones 2009). Pointing to the potential to move from 'catching up' (Abramowitz 1986) models of development towards 'environmental leapfrogging' (Watson and Sauter 2011), more recent work has highlighted the increasing importance of the emerging economies, especially China, in driving such green transformations (Lema and Lema 2012; Altenberg *et al*. 2008; Schmitz 2013). Key areas for research (largely neglected to date, but addressed in this project) are the political synergies and tensions between managerialist approaches to creating internationally-competitive sectors in low carbon innovation (requiring the development of technological capabilities, alongside appropriate supply-side and demand-side policy interventions) and the uncertain and unpredictable socio-technical and socio-political reconfigurations that are intrinsic to (low carbon) socio-technical transitions.

Such developments should be understood in the context of China's transition and its long history of widely differing approaches to the governance of its environment and innovation systems, from the era of 'Mao's war against nature', when numerous projects affecting the environment, such as hastily-built dams and land reclamation schemes, were carried out with what Shapiro (2001) described as utopian urgency and dogmatic uniformity, to China's eventual participation in the United Nations Conference on the Human Environment in Stockholm in 1972, a turning point that led to the establishment of the Country's first national environment agency, which would later become the Environment Ministry.

China's centralised and integrated national Five-Year Plans (FYPs) continue to set the country's key strategic and economic priorities. In the first decades of the People's Republic, these emphasised ever-higher production targets in industries such as coal and steel. However, the Sixth FYP (1981–1985), at the start of China's Reform Era, was the first to include an energy conservation programme. Around the same time, China passed the first of its many environmental laws and regulations, including the Environmental Protection Law (1979) and the Water Pollution Law (1984). In the 1990s, sustainable development first became a theme in Chinese Government literature. The Ninth Five-Year Plan (1996-2000) was the first to include the term (Geall and Pellisery 2012). The Fifteenth Party Congress, in September 1997, listed the, 'huge environmental and resource pressures caused by population growth and economic development, as major difficulties facing the nation (Meng 2012). In 2007, China's National Development and Reform Commission (NDRC), a key economic planning body, published the first national climate-change plan of any developing country. This established China's commitment to addressing climate-change mitigation and adaptation and participating in international cooperation on climate change, while also upholding the principle of 'common but differentiated responsibilities' and integrating climate change into other policies for national and social economic development.

Today, China's Twelfth FYP, 2011 to 2015, is the most prominent indicator of the priority accorded at an elite level, not only to environmental protection and climate-change mitigation, but also to low-carbon innovation as a core strategic concern. The Twelfth FYP, therefore, not only contains environmental targets and sectoral plans for various polluting industries, the most prominent being targets to reduce energy consumption per unit of gross domestic product (GDP) by 16 per cent and carbon dioxide emissions per unit of GDP by 17 per cent, but it also establishes seven strategic emerging industries that are afforded dedicated state funding, increased access to private capital and preferential policies (in tariffs, preferential loans and R&D funds), new energy, energy conservation and environmental protection, biotechnology, new materials, new information technology, high-end equipment manufacturing and clean energy vehicles. Having set a framework for strategic priorities, however, FYPs are only as significant as the policies that draw on the plan and the measures by which they are implemented, often particularly difficult tasks for local governments, as evidenced by the rush to meet energy intensity targets by the end of the Eleventh FYP (Geall and Pellisery 2012).

The implementation of such plans and policies should be understood in the context of the literature on China's environmental governance, which emphasises firstly the vertical fragmentation created by the proliferation of competing and overlapping decision-making bodies. While in theory, China's Ministry of Environmental Protection (MEP) is the highest Central Government institution regulating the environment, other departments and institutions often take the lead on particular environmental issues. Rather than being a monolithic system, Chinese environmental governance at the elite level is characterised by fragmented authoritarianism, with protracted bargaining between bureaucratic units, including ministries, advisory bodies and top-level National Leading Groups specifically established to coordinate cross-jurisdictional issues. Furthermore, such vertical fragmentation is matched by horizontal fragmentation. The considerable devolution of power to the provinces and localities, first introduced in the early Reform Era, has created a complex arrangement often described by the Chinese metaphor *tiao kuai* (branches and lumps), where Central Government authorities lack the capacity to demand enforcement of environmental laws and policies at the local level. Under China's relatively decentralised approach, local environmental bureaus, for example, are funded by local governments, rather than the MEP, meaning they tend to act in the interests of those very institutions they are tasked with regulating. Furthermore, economic targets often mean that local officials are rewarded politically by Central Government for achieving GDP growth, even if it comes at the expense of the local environment.

Chinese observers of the effects of this decentralisation note the extent to which a project system logic (Tian 2014; Qu 2012) has been instituted across government at all levels, a 'governance model between the traditional system and market mechanisms' (Tian 2014: 1) where local governments, for example, 'hanker' for projects to attract special funding from Central Government (Qu 2012: 10). In the field of low-carbon innovation, there is an illustration of these dynamics in Central Government plans around urbanisation, where cities dedicated to low-carbon development and electric mobility and more have been 'identified and encouraged to compete for solutions' (Fischer 2012: 5). While the ideological foundation of such a system is technocratic (Tian 2014: 3), its expert rationality often acts instead as cover for sectoral interests and interest groups. In practice, according to Kelly (2014: 57) such an arrangement, '[…] produces governance that sits uncomfortably half-way between full-scale planning signed off by ministers and the flexibility and canny differentiation of the market'.

Further, over the past 15 years, a growing number of influential officials and policymakers at the central level have supported citizen oversight, media coverage and other forms of public participation by civil society in order to improve local enforcement of environmental regulations, for example, through laws and regulations like the Environmental Impact Assessment (EIA) Law (2002), transparency initiatives on opening environmental information, and innovations like Hotline 12369, a phone tip-off line for citizens to report pollution incidents and environmental violations, operated by the Ministry of Environmental Protection (CCICED 2013). However, most institutional procedures for such public participation are vague and poorly enforced, and despite the flourishing of green NGOs, both registered and unregistered (there are now 492,000 legally registered social organisations in China, according to a 2012 Government report, of which many are green groups) environmental advocacy is closely monitored and subject to periodic crackdowns (Geall and Hilton 2014).

Nevertheless, concerns have increased about environment and health issues, particularly (though not exclusively) among China's newly enriched middle class, with opinions expressed more freely and rapidly than ever before due to increasingly ubiquitous social media and messaging technologies. A successful protest by residents in the South-Eastern Chinese city of Xiamen in 2007, opposed to a factory proposing to manufacture the petrochemical paraxylene (PX), began a trend of urban protests focused on the lack of transparency and accountability around potentially polluting developments

(Ansfield 2013). Since then, conflicts around, for example, the route of a maglev train route in Shanghai in 2007, a petrochemical plant in Sichuan province in 2008, a copper refinery in Shifang, Sichuan in 2012 and a PX project in Kunming in 2013, suggest that environmental governance issues represent a new social and political challenge for government, and, at the very least, an unprecedented pluralisation of opinion regarding pathways to sustainability in China (CCICED 2013).

Perhaps most striking in recent times, and most relevant to this working paper, has been the social and political effect of problems with China's food safety, from heavy-metal pollution and contamination by pesticides, veterinary drugs and food additives to the Sanlu milk scandal of 2008, when melamine-contaminated baby formula led to the deaths of six infants and made ill around 300,000 children. In Spring 2013, the sight of more than 10,000 pig carcasses floating down the Huangpu, the main river that feeds Shanghai, provoked not only understandable shock and revulsion, but also deeper questions about risk, directions of development, transparency, participation, accountability and governance. Drawing on debates around Beck's (1992) notion of a 'risk society', Yan (2012: 706) has argued that China, which has arguably, '[…] been affected by more food safety scares than any other on earth […]', has seen a rapid decline in social trust with '[…] far-reaching social and political ramifications […]'. The social and political implications of this decline in social trust, affected not only by the scale of the food safety problem but also the dynamics of environmental governance discussed above, and the unprecedented pluralisation of sources of information brought about by a changing media sphere and the Internet, will be discussed in later sections of this working paper and constitutes an important background to both the elite narratives of China's prospects for low-carbon innovation, and also to the emergent popular discourses around sustainability.

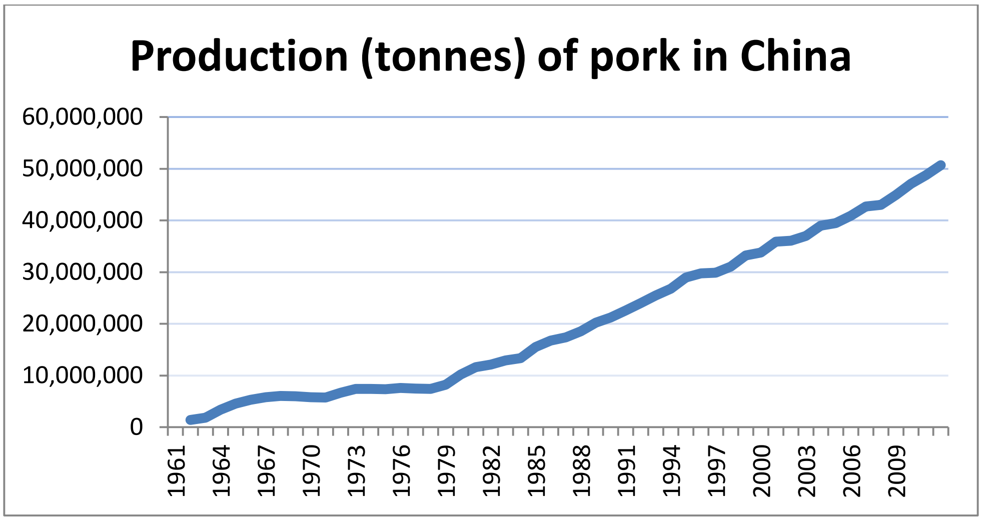
3. Chinese agri-food systems and the question of sustainability

Famously, China is home to around one-fifth of the world's population with only 8 per cent of its arable land (Ma and Adams 2014: 53). Famine, scarcity and rationing are all-too-recent memories for the country's leaders, and many of its people, and feeding China is hardly a matter of policy alone. The Chinese Government sees avoiding food scarcity as one of its highest priorities in order to maintain legitimacy, public trust and social stability, and one of the greatest achievements of the Reform Era (Ma and Adams 2014: 53). Agrifood systems are thus an aspect of the very constitution of power relations in China, which are in turn constitutive of China's contemporary social formation. Great emphasis has thus been placed on ensuring effective supply-side food policies throughout the past few decades. National policies on agriculture focus on production, including investments in chemical fertilisers, pesticides, irrigation and high-yielding seed varieties (Schneider and Sharma 2014: 13), but they also include the use of strategic reserves and export restrictions for staples, although rising demand means food and, particularly, feed imports have risen significantly (Garnett and Wilkes 2014: 104). China's reliance on feed exporters, including maize and soya from the USA and Brazil (for both of which China is now the largest importer of their agricultural produce), has burgeoned alongside the country's livestock sector (Levitt 2014). With overall grain self-sufficiency now less than 90 per cent, well below the target of 95 per cent, it has lead some academics to suggest controversially that China, '[…] no longer considers food security as one secluded country […], (Wang 2014a) and that its traditional policies of grain self-sufficiency might have been loosened or abandoned at an elite level (Hornby 2014). In any case, the centrality of agricultural policy for government decision-makers is indicated by the fact that in 2014, for the 11th year in a row, China's first central policy document of the year, called the *No.1 Central Document,* concerned rural reform and development (Xinhua 2014).

The avoidance of food scarcity in the Reform Era has been characterised by, or has even depended on, a huge increase in the production, sale and consumption of meat. Since 1980, average *per capita* meat consumption in China has quadrupled (Schneider and Sharma 2014: 11), although there is a particularly urban concentration of meat consumption, reflecting other stark inequalities in China's development (Ibid: 22; Vernooy 2012). The country has seen a massive rise in pork production and consumption, and pork has a great cultural and historical significance in China. The country has seen a five-fold increase in pork production since 1979 (FAO, see Figures 3.1 and 3.2), making China the world's larger producer and consumer of pork, with over half the world's pigs now living in China (Schneider and Sharma 2014: 14). With the aim of creating protein-rich, modern diets for urban middle-class consumers, in particular, the Chinese Government in the Reform Era has supported medium to large scale industrial pork production through subsidies, investments and preferential policies, particularly in the promotion since 1998 of 'Dragon Head Enterprises' to lead the consolidation of the agribusiness sector. According to the State Council in 2012, these Dragon Heads are. […] the major agents for constructing a modern agricultural system, and are the key to advancing agricultural industrialisation'(Ibid 2014: 21-24).

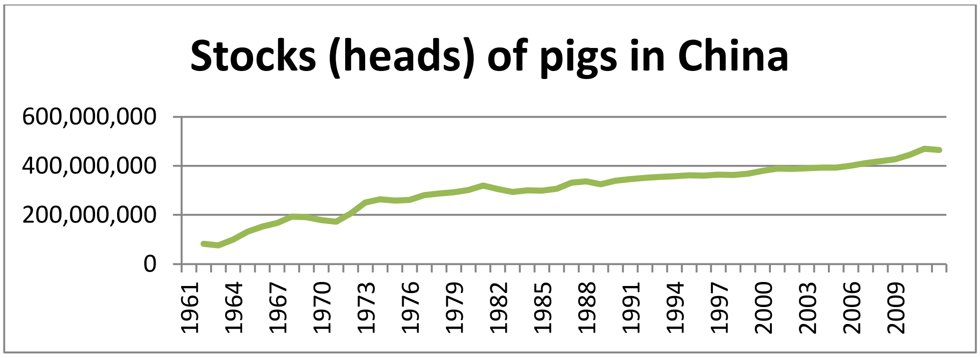
This rapid expansion of agricultural production and industrial meat agriculture has had a significant environmental footprint in China, in the forms of soil and water pollution, as well as greenhouse-gas emissions (MEP 2013). Agriculture is a major source of nutrient and mineral pollution in China's water. Studies have found that livestock waste, in particular, is a large contributor to the substantial emissions of nitrogen, phosphorus and heavy metals including copper and zinc in China's water supplies. In 2010, a pollution census found that livestock was the largest contributor to run-off pollution from land into waterways in China (Qiu 2010). Livestock manure is responsible for 38 per cent and 56 per cent of the total nitrogen and phosphorus discharges into China's surface waters, respectively, where inorganic phosphorus is often added to pig feed (Garnett and Wilkes 2014: 54). Overuse of nitrogen and phosphorus fertilisers is also common (Li et al 2012).

Figure 3 1: Production (tonnes) of pork in China, 1961-2011



Source: Food and Agricultural Organization of the United Nations, Statistics Division (FAOSTAT)

Figure 3.2: Stocks (heads) of pigs in China, 1961-2011



Source: FAOSTAT

It is not surprising, therefore, that the annual assessment for 2012 from the Ministry of Environmental Protection concluded that the, '[…] rural environment is very grim […], with more than ten per cent of China's river water quality rated worse than Grade V, the most polluted grade (MEP 2013; China Water Risk 2013). Harmful algal blooms caused by an excess of nutrients, particularly phosphorus, are increasingly common social disasters, as much as they are environmental problems, severely affecting local water supplies, even leading to the cut-off water supplies to entire cities and runs on bottled water (Stone 2011a). Wang Shiyuan, vice-minister of land and resources, recently said that about 3.33 million hectares of China's farmland are too polluted to grow crops (Wang 2014a) and the Ministry of Environmental Protection announced in April that one-fifth of China's arable land is polluted to some degree (Wang 2014b). Contaminated land and water have thus placed increasing focus on how the sustainability of Chinese agriculture may affect food safety and security, although elite and popular responses differ in their proposed solutions.

China's No.1 Central Document (see above) concerning rural reform and development outlined 'the importance of environmental protection' and at the Communist Party's November 2013 Third Plenum, it was proposed that China's 'red line', which states that 120 million hectares of arable land must be maintained for food security, be matched with an 'ecological red lin'' that should ensure protections from pollution and development. This concept later became an aspect of China’s revised Environmental Protection Law that, according to one of the law’s authors, reflected 'the Government's intention to hold onto 'ecological security' baselines' (Liu 2014). However, despite the role of the rapid expansion of China’s industrial agri-food system in driving pollution and associated food safety problems, Chinese policymakers also see a move from small-scale towards industrial pork production as the solution to food safety problems, echoing a popular discourse that equates industrial agriculture with modernisation and development, while blaming smallholder farmers for food safety scandals (Schneider and Sharma 2014: 22). This reflects a 'strong consensus within Chinese policy circles that increasing the scale of production can help in addressing environmental impacts', by allowing the application of 'precision management techniques' as well as facilitating better inspection and regulation (Garnett and Wilkes 2014: 57). Garnett and Wilkes conclude, however, that there is 'only limited evidence' that larger-scale land holdings result in improved nutrient use efficiency or that larger-scale livestock operations have lower emissions per unit of output. They note, for example, that specialisation rather than scale, may be the key to environmental good practice in China’s livestock operations.

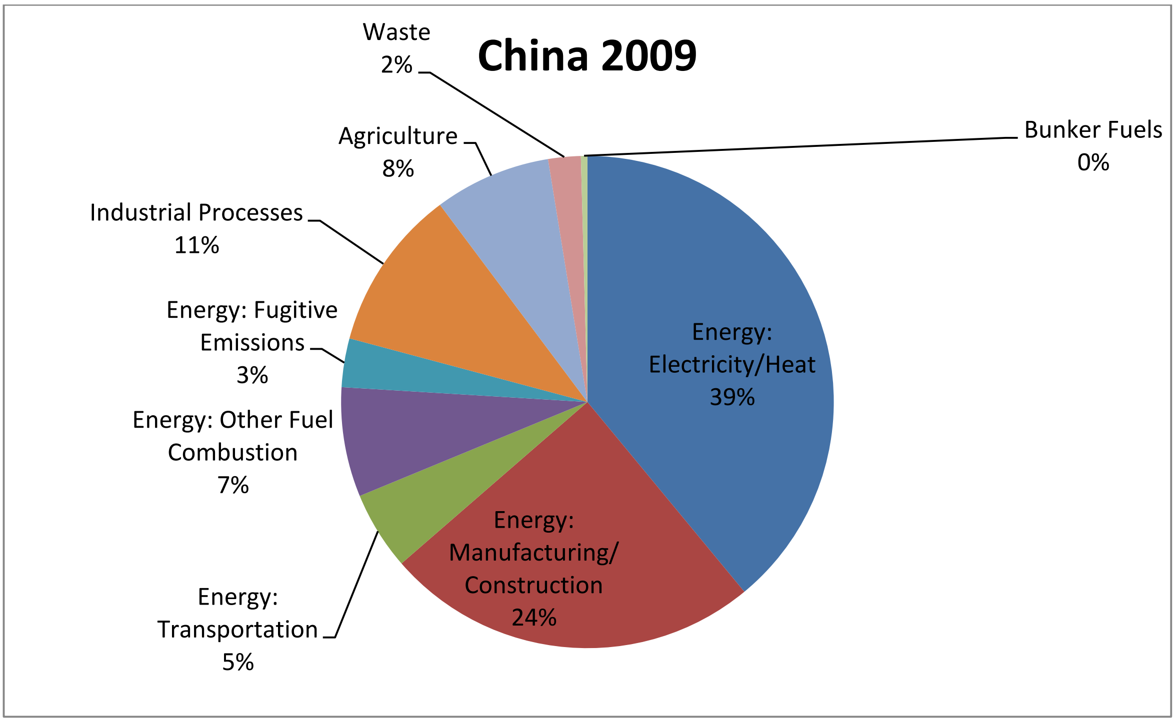
Furthermore, industrial agriculture is a major contributor to climate change. One estimate from the World Resources Institute (see Figure 3.3) suggests the agriculture sector accounted for 8 per cent of China’s greenhouse-gas emissions in 2009. Such estimates vary depending on how the boundaries of the agriculture sector are defined, but methane from enteric fermentation from livestock and CO2 from synthetic fertiliser production and use are the largest sources of agricultural greenhouse-gas emissions (Garnett and Wilkes 2014: 60). In 2005, according to the NDRC, direct emissions from livestock production and manure management contributed about six per cent of China’s total greenhouse-gas emissions, while life-cycle assessments of large-scale pig farms in China suggest that feed production accounts for 81 per cent of total livestock-related emissions, accounting for around 10 per cent to 15 per cent of China’s crop-related emissions (Garnett and Wilkes 2014: 62).

One source estimated that the manufacture and use of synthetic nitrogen fertilizer accounted for some nine per cent to 15 per cent of China’s total greenhouse gas emissions (SAIN Online 2011), with another finding that for every tonne of nitrogen fertiliser manufactured and used in China, 13.5 tonnes of CO2-equivalent gases are emitted, compared with 9.7 tonnes in Europe (Zhang *et al*. 2013). According to Garnett and Wilkes (2014: 61) there are three main reasons for this large contribution from fertilisers: the 'relatively inefficient technologies' widely used in fertiliser manufacture, with coal as the main energy source; the urea fertilisers that tend to be used in preference to ammonium nitrate; and the substantial over-application of fertilisers. FAO statistics show an increase of 79 per cent in total emissions from the manufacture of nitrogen fertilisers over the two decades towards 2011 (see Figure 3. 4).

This is before one considers the climate-change effects of wider changes in the food retail sector, particularly the ‘supermarketisation’ of food retail (Hu *et al*. 2004; Reardon *et al*. 2005) and its relationship to changes in food storage (such as refrigeration), food transport and imports, patterns of urbanisation and changing mobility practices.

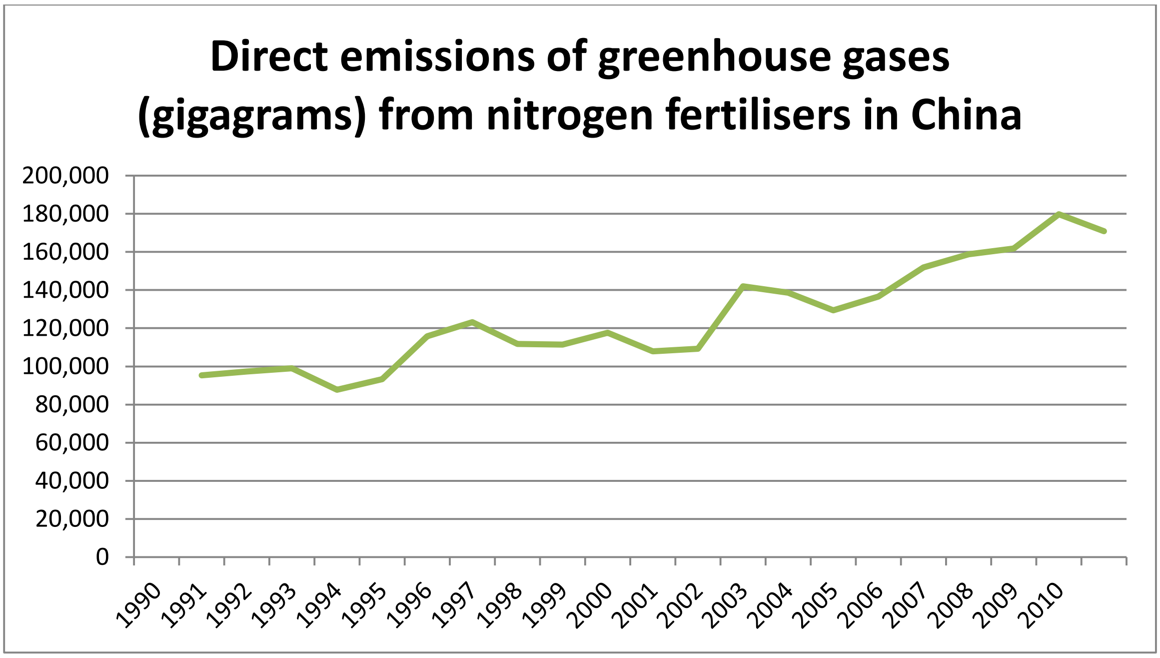
Based on the challenges described above, we next describe in detail two potential pathways (Leach *et al*. 2007) characterised by the case studies listed above, examining in turn the prospects for associated transitions to low carbon and sustainable agri-food systems, the political issues surrounding these potential transitions and the associated considerations with respect to practice.

Figure 3.3: Greenhouse gas emissions in China by sector and energy subsector, 2009



Source: World Resources Institute. (Chart excludes land use and forestry, since it is a net carbon sink)

Figure 3.4: Direct emissions of greenhouse gases from nitrogen fertilisers in China, 1991–2011



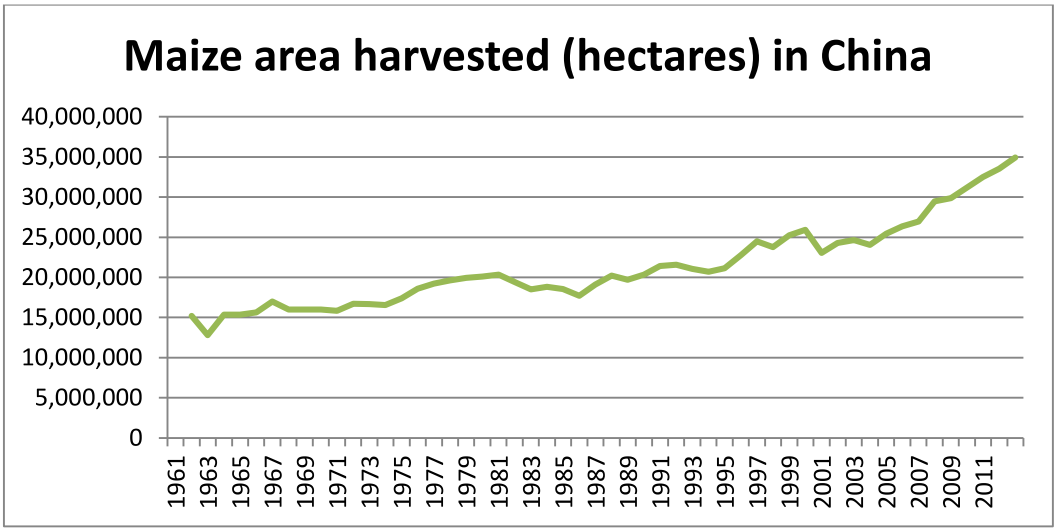
Source: FAOSTAT

4. Case Study 1: Phytase maize

4.1 Phytase maize: prospects

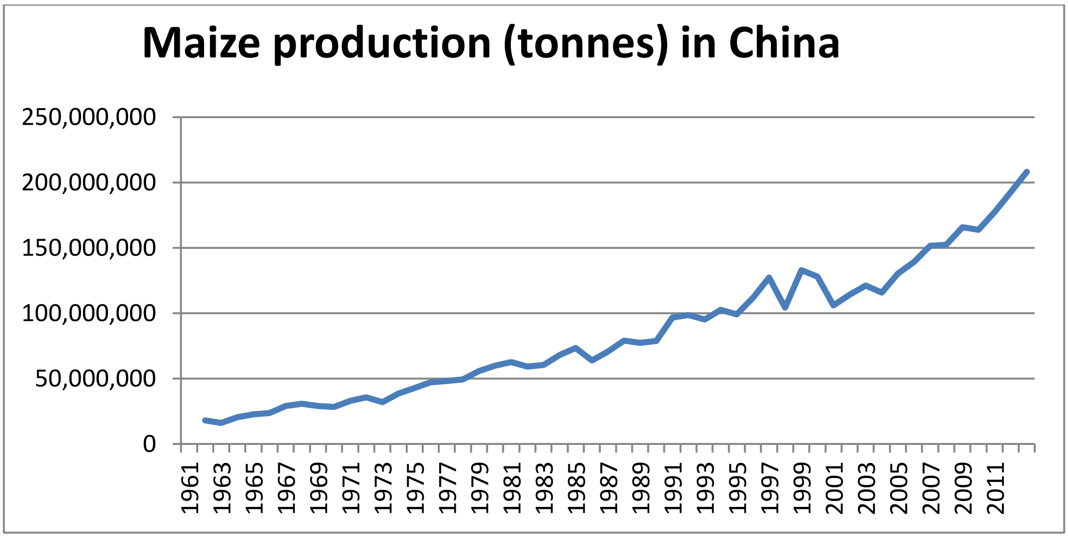
China's rising meat consumption and production, detailed above, has had a significant impact on patterns of maize production and consumption. Maize is now the number-one animal-feed and number-three food crop in China (Zhang *et al*. 2010). While 50 years ago, maize was grown on around 15 million hectares across China, by 2011, this figure had climbed to more than 34 million hectares for both food and feed (FAO 2012, see Figure 4.1), with more than a 12-fold increase in annual overall production (see Figure 4.2). Of this maize crop, 68 per cent is now grown for feed (see Figure 4.3). Upward-trends in production have been seen in other countries such as the USA, but do not compare with the rates of increase in China.

Figure 4.1: Maize area harvested (hectares) in China, 1963–2012



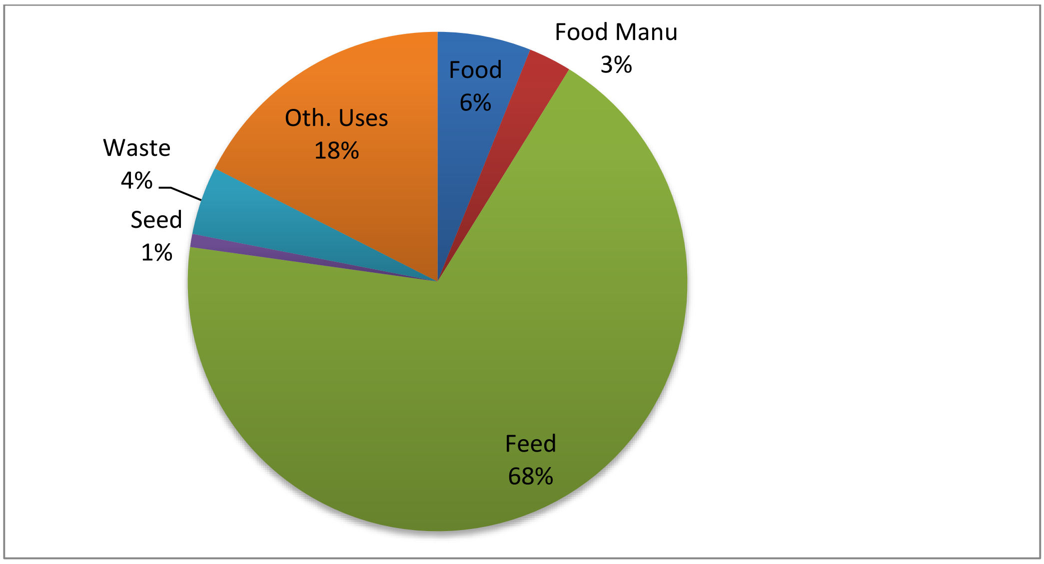
Source: FAOSTAT

Figure 4.2: Maize production (tonnes) in China, 1963–2013



Source: FAOSTAT

Figure 4.3: Maize utilisation in China, 2009



Source: FAOSTAT

China's maize agriculture, in common with other crops, has considerable environmental effects, as outlined in the previous section. Intensive forms of maize production at increasingly larger scales use large amounts of synthetic inputs, such as fertilisers and pesticides, and produce additional carbon emissions through mechanisation (Burney *et al*. 2010). In the context of climate change, these require redirecting innovation towards more sustainable and low-carbon modes of agricultural production. One such potential innovation is phytase maize. Phytase is an enzyme that breaks down phytates, chemicals that are found in maize and act to inhibit the uptake of phosphorous as a nutrient in monogastric animals, such as pigs and chickens. Phytase is therefore often used as an additive for animal feed and is mandatory in Europe, Southeast Asia, South Korea, Japan and Taiwan, primarily because its use reduces phosphorous pollution from animal faeces (BusinessWire 2009). Transgenic high-phytase maize, which would eliminate the need for such additives by enabling pigs fed on the crop to absorb more phosphorous directly, has been claimed to have various environmental and greenhouse-gas mitigating benefits, principally:

- more efficient land use as in comparison to conventional maize, phytase maize should, due to the higher bioavailability of phosphate, require less feed per animal, reducing the requirement for land or fertiliser for a given meat yield;

- direct energy savings as a result of the active ingredient being made in the plant rather than the factory. One of the scientists involved in developing the technology, Chen Rumei, told SciDev.net, 'If this technology is commercialised, we can save up to 450 million yuan (US$60 million) per year in energy costs used to produce industrial phytase enzyme additives'' (Chen 2009);

- environmental benefits associated with avoiding pollution from phosphorus and other discharges.

Phytase maize was developed over seven years by the Chinese Academy of Agricultural Sciences and licensed to Origin Agritech Limited. The company claims that phytase increases phosphorus absorption in monogastric animals by 60 per cent and reduces the release of phosphorus in faeces by 40 per cent. It also claims that the worldwide phytase potential market size is US$500 million, including $200 million for China alone, citing the China Feed Industry Study (Origin Agritech 2008).

Origin Agritech is a leading Beijing-based agricultural biotechnology company, which was listed on the NASDAQ Stock Market in 2005 and specialises in research and development, production, sale and distribution of crop seeds, accounting for seven to eight per cent of China's crop seed market. (Origin Agritech 2013) The company operates 16 marketing centres, nine processing centres and ten breeding stations across China. Regarded as a strong candidate in the agricultural field under the 'Going Out' (or 'Go Global') strategy, a national policy to encourage overseas investment, first launched in 1999 and later incorporated into the Tenth FYP (2001–2005), the company has commercialised a range of proprietary seeds, including ten non-transgenic corn hybrids, six rice hybrids and two canola hybrids. It also holds a US patent on a synthetic glyphosate-resistant gene for use in transgenic maize agriculture, an indicator of its status as a competitor to major multinational agricultural biotechnology companies, in this case, Monsanto, the leading producer of the herbicide glyphosate, as well as genetically engineered seeds.

Origin Agritech receives significant Chinese Government support. In 2012, the Ministry of Agriculture (MOA) awarded Origin a Breed-Produce-Distribute Vertically-Integrated (BPDVI) Crop Seed Licence as part of a Central Government effort to 'regulate the seed industry and promote consolidation [under which companies can expect] ongoing government support and certain incentives including further tax break [sic] and financial subsidies to crop seed research and development' (PRS Newswire 2013). It has also received government financial subsidies. For example, in 2012, the Government supported a new production line in Linze, Gansu province, with 14 million yuan (US$2.21 million) in subsidies. Origin also received a government subsidy of 10.90 million yuan (US$1.72 million) for the land use rights for a corn seed processing centre in Xinjiang, northwestern China (Origin Agritech 2013). Origin's company filings state it has received government subsidies for research and development, totalling 1.55 million yuan in 2012 and 16.11 million yuan in 2013, accounting for around four per cent of the company's research and development budget of 37.63 million yuan in 2012 and 38 per cent of the company's research and development budget of 42.16 million yuan in 2013 (Ibid).

On 27 November 27 2009, the MOA granted a biosafety certificate for phytase maize. However, before the product could be officially commercialised it needed to complete the seed variety registration process (GAIN 2009). Origin Agritech had said it hoped this would be completed in 2013, but the authorities have blocked or delayed the final approval process. SciDev.Net reported that the MOA's original Biosafety Management Office document (published on their website in October 2009) specified the validity of the biosafety certificate from August 2009 to August 2014, for planting in Shandong province in eastern China. It is unclear what has been happening at the central level and how different elements of the new administration look upon these live policy questions, but public sentiment may have been a significant factor in the delay of the registration process and the delayed decision to renew the biosafety certificates, an issue that is discussed in the following section.

4.2. Phytase maize: politics

Political scientists have often criticised the lack of attention to political realities in studies of low carbon transitions (Some of these concerns have more recently been addressed by studies of policies for system innovation in Europe (Kern 2011), for example focussing on shielding, nurturing and empowering the solar hotovoltaic (PV) innovation niche in the UK) and the Netherlands (Verhees *et al*. 2013). These kinds of questions have, to date, been severely under researched in the agricultural domain, especially in China.

Phytase maize has been praised in Chinese state-run media as a symbol of low-carbon innovation. One article in the state news agency Xinhua (Zhang 2010) described it as a, 'promising the low-carbon economic era (低碳经济时代)'. The article said, 'as one of the strategic emerging industries, biological breeding (生物育种) is an extremely important aspect of the low-carbon economic era', before going on to describe the benefits of phytase maize for greater energy efficiency and emissions reduction.

Another article in Xinhua headlined 'Environmentally Friendly Maize (环保玉米) and environmentally friendly pigs', by the prominent science writer Fang Zhouzi (2012), described the benefits of phytase maize in some detail and concluded that, 'genetic modification is often demonised as an environmentally destructive technology, but as we can see, the clever use of genetic modification will help protect the environment'. One study of two official, national newspapers, the People's Daily and Guangming Daily, from 2002 to 2011, concluded that Chinese reporting of genetially modified (GM) crops had emphasised the benefits of transgenic organisms and no articles had portrayed them in a negative light (Du and Rachul 2012).

Underlying this dominant narrative are not only technological considerations but also political dynamics. China's national policies place strong emphasis on building innovation in agriculture. In the latest No.1 Central Document, priority 'is given to innovation in agricultural technology and building agricultural markets'. In 2012, the same document chose, 'accelerating the scientific and technological innovation to strengthen supply of agricultural products' as its core theme, with an emphasis on promoting 'industrialization, urbanization and agricultural modernization simultaneously', while increasing 'farmers' incomes and [maintaining] the social harmony and stability in rural areas'. China's Central Government policies clearly support the development of technological capabilities in transgenic science and technology, a focus that dates back to the 1980s when China became one of the first countries to experiment with genetically modified crops. For example, national policies support the use of cotton engineered with *Bacillus thuringiensis* (Bt) to reduce synthetic insecticides in 'high potential areas' (Van Zwanenberg *et al*. 2011). Agricultural biotechnology is also one of the key components of the Medium-Long Term Plan for Science and Technology (2006–2020) and an area in which China's potential for indigenous innovation may at some point challenge incumbent leading US and European firms. Based on a 'confidential study prepared for China's State Council in 2001', Ho *et al*. (2006) point towards a call for a 'dual strategy' for imports, differentiated on the basis of those crops which China was or was not able to achieve commercial production. Whilst exporters might see these decisions as in opposition to the rules of the World Trade Organization (WTO) (which China joined in 2001), Hugh Grant, Chief Executive Officer of Monsanto, prefers to stay out of such debates, stating, 'I think that's an evaluation that has to be made in China, for China, by Chinese scientists and regulators'. (Zheng *et al*. 2013)

China's Twelfth Five Year Plan (2011–2015) states that China will 'speed up the innovation and application of biotechnology breeding in agriculture', and identifies agricultural biotechnology as one of the seven Strategic Emerging Industries supported by subsidies, tax breaks and other preferential policies (see above). The Ministry of Science and Technology's (MOST) Twelfth Five-year Plan for Development of Biotechnologies also identified agricultural biotech as playing a significant role in developing the agricultural industry and securing national food security, and MOA's Twelfth Five-Year Plan for National Agriculture and Rural Economic Development supported the accelerated development of agricultural biotech through breeding and producing new varieties of animals and plants, bio-pesticides, veterinary drugs, vaccines, bio-fertilizers. China has so far granted safety certificates for transgenic cotton, papaya, rice and maize crops, according to *Xinhua*. However, only GM cotton and papaya have been authorised for commercialisation (An 2013).

In the context of the 'global propaganda war enveloping GM crops' (Keeley 2005: 155) China has often been cast in the role of showing 'the way forward for developing countries' without the influence of 'troublesome non-governmental organisations (NGO) panicking farmers and consumers', an international view that resonates with technonationalism within China's elite circles. However, Jia and Liu (2014: 34) are among those observers pointing to the emergence of a wider, popular counter-narrative in China which is concerned or critical about GM technologies, in contrast to the official media stance of support for transgenic crops as an element of agricultural modernisation. The particular reactions of farmers and consumers will be discussed further in the next section, but it is increasingly clear that such a counter-narrative not only has its representatives at elite levels, but also that public opinion is being taken into account by government in decision-making around agricultural biotechnology, due to political legitimacy and social stability concerns. While the proliferation of concerns around environmental health, safety and risks has led some (Suttmeier 2008: 130) to suggest China must urgently address its 'underdevelopment of institutions for managing environmental and technological risks' and its tendency to overlook the need for 'decentralized mechanisms for identifying risks […] and for ensuring the accountability of public and private actors responsible for creating hazards', most responses to controversy around GM in China so far have comprised top-down regulatory decisions or deficit model type approaches to address public 'misconceptions'. Government increasingly identifies environment-related health problems as a major source of social instability. According to one government official, environmental concerns are the most common catalyst for 'mass incidents' (Bloomberg 2013), an euphemism for protests and riots, and the Ministry of Environmental Protection notes that frequent environmental incidents have 'caused a serious threat to the health of the masses and to social stability, and [have] had a very negative impact, both domestically and abroad'(Holdaway 2013).

Recently a well-known Chinese state television host made a critical documentary about the controversy around GM in US academic circles. The documentary talks to a range of actvists, scientists and regulators, and features fringe views emphasising an apparent correlation between diseases such as autism and the consumption of GM crops in the United States. In response, the science writer Fang Zhouzi, whose article about phytase maize (see above) had praised its environmental potential, argued that GM foods were safe. The resulting public debate was characterised in media articles as a high-profile celebrity feud (Zhang 2013). Writers, activists and academics, some of them government-linked, from China's 'New Left' and neo-Maoist movements have taken a particularly strident stance in their opposition to GM technologies, a position which one article in state-run Global Times characterised as, '[GM is] a conspiracy orchestrated by Western countries to stop the Chinese reproducing' (Zhang 2013). Evidence of this strain of thinking at an elite level comes from a training video, 'Silent Contest', produced by the People's Liberation Army (PLA) National Defense University Information Management Centre, and shown to Chinese army officers, and later leaked online, which uses transgenic crops as an example and a wider political, by stealth. Over stock and newsreel footage, a voiceover states:

> The word 'transgene' refers to a process of modifying a species for a specific need. It involves using the scientific technique of taking a certain necessary gene segment from one organism and putting it into another organism to create a new combination of genes. The transgene appears to cause no harm to the targeted species, but just uses modern genetic technology to introduce a small improvement in that species. However, this tiny genetic change, no matter how small it may look, not only destroys the full features of the original species, but also places the new species under the control of the entity that introduced the change.
>
> The United States has added transgenic food to its national strategic resources. Its push for global adoption is in fact a means for the US to realise its control over the world by controlling global food production. Then, having the same goal, will the US design and implement a 'political transgenic' strategy in the arena of an entire society? The answer for sure is, 'Yes'.
>
> In 1945, director of the Central Intelligence Agency Allen Dulles told the House Foreign Affairs Committee, 'A person's mind and thoughts can change. If we get a person's mind to be confused, we can then change his values and concepts unnoticeably and make him believe in these values that have been changed'.[1] (PLA training video *Silent Contest*)

[1] Dulles did not become director of the CIA until 1953, and the authors of this paper could find no record of such a speech.

Others have drawn explosive analogies with the Opium Wars (The Economist 2013), and in 2013 there was even popular speculation that dead pigs dumped in rivers had been killed by GM maize (Ho 2013). Activists have written open letters to the government claiming that 'China is being exploited by agribusinesses' (Stone 2011b). Perhaps in reaction to rising public concerns, or due to genuine fears at an elite level about the risks of importing US GM crops, in late 2013 China denied entry to thousands of tonnes of a variety of insect-resistant Bt maize (MIR 162, produced by Syngental) from the United States, which apparently had not been granted a security certificate, not for the first or the last time.

Yet at the same time, government-linked scientists attempted to push the government to 'begin promoting industrial cultivation of GM rice as soon as possible' (Cui and Yu 2013). Like phytase maize, GM rice has obtained safety certification but has not been approved for commercial cultivation. In their petition, the scientists stated that 'the promotion of industrialised cultivation of GM rice can wait no longer, otherwise we will harm the national interest. The commercialisation of GM food will be unable to develop, which will have an enormous impact on scientific research' (Cui and Yu 2013).

Despite this pressure from the scientific elite, there were significant delays in the renewal of the the biosafety certificate for phytase maize by the Ministry of Agriculture after they expired. Official justifications for this delay were notably absent. In August 2014, Wang Jing from Greenpeace China stated, 'We believe that loopholes in assessing and monitoring [GM] research, as well as the public concern around safety issues are the most important reasons that the certifications have not been renewed" (Normile 2014). Others such as Huang Jikun argued (for Bt rice, for which the biosafety certificates were also delayed) that as China has now reached self-sufficiency without GM varieties, there is less economic rationale to move towards commercialisation, but that the decision does not reflect a change in China's overall policy regarding agricultural biotechnology (ibid). In other areas, such as Bt maize, for example, the government is increasing its support for research, possibly as GM corn has faced less public opposition, in part because it is primarily fed to livestock (ibid). However, in an apparent turn-around in late 2014, the government renewed the certificates, allowing scientists at the Chinese Academy of Agricultural Sciences to conduct research on the maize in Shandong province for a further five years (Ministry of Agriculture 2014).

A major objective of this project is to further uncover and analyse the interplay between the various technical and political factors that have determined, and will continue to shape, China's approach to phytase maize and transgenic crops more generally. The country's political debate is likely to remain intense, and is likely to be shaped more than in previous eras by the preferences and practices of China's producers and consumers.

4.3. Phytase maize: practices

Alongside production, changing patterns of food consumption, a significant contributor to climate change, have come under increasing research attention over recent years. Recognising the role of user behaviour and practices in enabling transitions to more sustainable systems, scholars and governments, including that of the United Kingdom, have started to focus on the role of beliefs and values in determining behaviour change, with a view towards engendering more sustainable consumption patterns, either through coercion or through fostering grassroots engagement (Ockwell *et al*. 2009; Spaargaren *et al*. 2014). Practice theorists (Schatzki *et al*. 2001, Warde 2005) critique the notion that that behaviour (and potential behaviour change) can be seen as individual and based on rational, cognitive processes, highlighting findings that such practices are social, habitual or routinise 'variously sustainable practices come into existence, how they disappear and how interventions of various forms may be implicated in these dynamics', as demonstrated in studies of daily laundering and urban mobility (Shove and Walker 2010).

Research in this vein in the agri-food domain has, for example, focused on the diffusion and role of specific technological artefacts in orchestrating aspects of food consumption and provision, such as

Hand and Shove's 2007 study on the freezer, or the changing temporal aspects of the practice of eating (Southerton *et al.* 2011). In taking practices seriously in this study of agri-food systems in China, we will attempt to pay due attention to similar technological and social dynamics and attempt to understand the collective, culturally-embedded routines characteristic of the everyday lives of different producers and users implicated in these potential transitions. The producers and users in the these two case studies will be different, but in this one might include: maize farmers, whose relevant practices are seed choice and selection, purchasing and agricultural management practices and routines; livestock rearers feeding maize to their animals, whose relevant practices include feed choice and purchasing; and food processors using maize or maize-fed meat as ingredients and involved in the marketing and labeling of GM and non-GM foods.

Practices around genetically-modified seed selection, sourcing and agricultural management have been studied with respect to transgenic Bt cotton (Van Zwanenberg *et al*. 2011), and point towards the importance of trust relationships with seed dealers, a varied reliance on different sources of information and a tendancy towards diversification of seed sources and varieties. In-depth studies of the potential changes in practice associated with the introduction of transgenic maize varieties are, to our knowledge, absent. One relevant possibility that could be better studied with attention to practice is that the increased efficiency introduced by phytase maize in the livestock system is effectively negated by the increased production and consumption of pigs, the so-called rebound effect or 'Jevons Paradox' long observed in the history of technology. Studying potential changes in farmer routines associated with an, as yet uncommercialised, technology raises a number of challenges (returned to later). However it will be possible to study the perspectives and practices of current maize farmers (as well as livestock rearers and others) to investigate the kinds of factors determining their current behaviour. This will provide useful insights for policy makers aiming to bring transgenic staple crops into existing agricultural production systems, but the implications for practice of reconfiguring such systems are hard to predict.

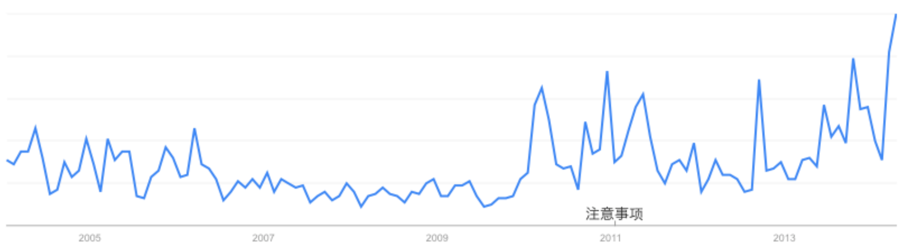
Perhaps most significantly in this section are the practices of the end consumers of maize, meat or processed food. The 'consumer' (消费者) first emerged as a feature of Chinese social life in the Reform Era, and while there is little in the way of 'organised promotion of ethically motivated consumption' (Klein 2009: 77), purchasing practices affected by buyers notions of risk and uncertainty will increasingly be felt by the market, as well as shared in the public sphere, particularly the online public sphere and other spaces that tend to host an evolving discussion around sustainability questions. In 2012, a graduate student at Fudan University in Shanghai started the website 'Throw it out of the Window', (掷出窗外, www.zccw.info), its name a reference to US President Theodore Roosevelt who was said to have thrown his breakfast sausage out of the window after reading about conditions in the Chicago meat-packing industry in 1906. The site, staffed by student volunteers, compiled information from media reports about food safety risks across China. Soon after its launch in May 2012 the site crashed under the heavy demand from web users (Wu and Han 2012).

Before the safety certificates for phytase maize were issued, some researchers suggested that food labelling was not yet a contentious issue and that, at least in the urban East, when commercialised it would not be likely to meet much resistance in China (Huang *et al.* 2006). Since then, an emerging narrative that draws attention to the risks of GM foods, in particular, seems to have emerged with debates around the Chinese-developed insect-resistant Bt63 rice, sparked by a report in the influential Guangdong based newspaper Southern Weekend in 2004, which suggested scientists had attempted to commercialise the GM rice 'for their personal commercial interests'. This, Jia and Liu (2014: 34) noted, was the first case of the Chinese public questioning 'science and the people doing science', which ultimately resulted in a halt to the process of commercialisation. In other words, consumers' concerns were related to existing political concerns about the risk–regulatory framework, no doubt conditioned by the wider decline in social trust, described above, regarding food and its regulation, further bolstered by the revelation that transgenic rice, though unauthorised for commercial cultivation, was showing up in exports from China to Europe and Japan (Herring 2009). In 2004, the same year that the Southern Weekend article appeared, one Ipsos survey on GM foods in Beijing, Shanghai and Guangzhou, commissioned by Greenpeace, found that 57 per cent of people surveyed were 'against GM foods' and only 16 per cent would eat GM foods (Zi 2010: 110). That rice is a staple food with cultural and historical resonances is often cited as a particularly important faultline and the reputation of GM rice, and similar technologies in general, may have been damaged even further by a widely reported scandal in 2012, where parents had found their children were being fed GM rice in a study on health effects conducted without full, informed consent (Hvistendahl 2012).

Today, 'public debate about food safety in China is characterised by a sense of extreme anxiety and uncertainty' (FORHEAD 2014: 53–4). Surveys indicate that the public regards food safety as the 'second greatest risk in daily life, with 92 per cent expecting to be the victim of food poisoning in the next year' (FORHEAD 2014: 53). Concerns about GM foods seem to confirm that, similarly, Keeley (2005) was right to suggest that China's 'embrace of the biotechnology revolution [was] not as unequivocal as much global discourse suggests' (Keeley 2005: 157) particularly among end consumers. The continuing volume of the public debate among consumers can be implied through online search data. Google Trends gives a sense of the frequency of keyword searches on the Chinese mainland and (although this should not be treated as a generalisation beyond Google's particular user-base which is not the most widely used search engine in China (Baidu has the greater market share), is impeded by censorship, and while internet penetration in China is growing, such a sample is clearly biased towards urban middle-class populations) such data has been known to at least hint at local anxieties around particular topics. For example, Google Trends data on web searches for 'flu symptoms have often been cited as an effective predictor of local outbreaks of the virus in the US (Cook *et al*. 2011). According to Google Trends, the term 转基因 (GM) has seen near-constant interest as a search term over time, with a recent increasing trend (see Figure 4.4). Further, increasing popular search terms related to GM include 'GM maize' (玉米转基因) and 'GM risk' (转基因危害) (see Figure 4.5).

Trends such as these, and others, will be investigated as part of a study of the drivers of, and implications in terms of practice associated with, an agri-food system transition associated with transgenic phytase maize. We now turn to the second potential pathway for systemic change, centred around organic and ecological agriculture.

Figure 4.4: Google web searches for 转基因 (GM) in China from 2004 to April 2014



Source: Google Trends

Figure 4.5: Related web searches to 转基因 (GM) on April 3, 2014, with English translations

热点'Hotspots', i.e. top related searches	上升'Rising', i.e. new search trends

转基因食品 GM foods	水稻转基因 Rice GM
转基因生物 GM organism	玉米转基因 Maize GM
转基因技术 GM technology	转基因危害 GM risks
大豆转基因 Soybean GM	转基因油 GM oil
转基因安全 GM safety	转基因玉米 GM maize
转基因大豆 GM soybean	非转基因 Anti-GM
大豆 Soybean	转基因中国 GM China

Source: Google Trends, April 2014

5. Case Study 2: Agro-ecological approaches to maize production

5.1. Agro-ecological and sustainable agriculture: prospects

During the Reform Era, at the same time as core state policies emphasised the role played by agricultural biotechnology in the development and modernisation of agri-food systems, there has also been interest in upgrading low-external-input maize agriculture in China through conventional (including participatory) plant breeding, improved management practices and supply chain innovation towards high-quality products to serve wealthier urban and overseas markets (Paull 2007). These approaches seek to develop agricultural practices that are more sustainable and low-carbon, but stand in marked contrast to the top-down, IP-intensive approach to innovation that has characterised the development of phytase maize. They are designed for, and practiced by, farmers at much smaller scales than those possible with much of the intensive farming that characterises the model described in Case Study 1, and often sit within polyculture systems alongside the cultivation of other crops, and combined with other, diverse, livelihood strategies. Agro-ecological farming dramatically reduces the use of nitrogen fertiliser and, as a direct result, the carbon intensity of production. Reduced pollution from nitrates and phosphates, and thus reduced food safety and environmental risks, are additional benefits. While in the early years of reform, Chinese food shoppers still had little variety, by the 2000s food supplies were abundant and new kinds of food safety hazards had helped to create the conditions for a market in 'green', 'organic' and 'no public harm' foods (Klein 2009: 86–7).

Urban environmentalists in China have promoted the production and consumption of organic and sustainably farmed foods. For example, the Pesticides Eco-Alternatives Center (PEAC), an NGO based in Kunming, Yunnan Province in southwest China, a region known for its long growing season and relatively low population density, which has helped to make it a supplier of organic and green produce for many other regions in China, carries out research on pesticide use and holds regular farmer training workshops focused on the health risks of pesticides to the environment, consumers and farmers themselves (Klein 2009: 74-6). Li Yuan, a journalist for Spring City Evening News, also in Kunming, organises field trips for volunteers to assist farmers using sustainable methods, has opened a small facility where those living in urban communities can learn how to get involved in raising their own, organic crops, and has produced a 25 minute educational film, 'Ecological Growing', with support from the Yunnan Association of Science and Technology, a government think-tank (Scally 2014).

Indeed, state efforts, while at a much smaller scale than the backing for agricultural biotechnology, for example, have also supported the development of organics and similar foods in China. In the 1990s, China's Ministry of Agriculture established the Green Food Development Centre in Beijing and the State Environmental Protection Agency (later upgraded to the Ministry of Environmental Protection) set up the Organic Food Development Centre in Nanjing. These two organisations, respectively, created the categories of chemically reduced green foods (绿色食品) and the certification scheme for organic foods (有机食品). Certified green foods are much more widely produced than organic foods in China. By 2005, more than 500,000 hectares were dedicated to certified products, with over 1,000 companies involved (Vernooy 2012), such as Sino-Agriculture, an offshoot of a Taiwanese organic food company, which opened vegetarian organic centres in cities in eastern China and operates a farm near Kunming (Klein 2009: 85). The area under production and the total production have continued to expand since then, with organic vegetables becoming available in major supermarkets in Chinese cities.

Other efforts have focused on the use and maintenance of broad genetic diversity and self-reliant local agricultural systems to improve resilience to climate change and provide a basis for local adaptations. Increasing erosion of agricultural biodiversity (as a result of rapid uptake of small numbers of commercial varieties) reduces resilience to biotic and abiotic (including climatic) shocks and stresses across the country, especially in more sensitive areas in the southwest where maize plays an important food security role. Forty years ago, Chinese farmers grew at least 12,000 open-pollinated varieties, whilst today farmers in the main maize growing areas have to rely on only about 200 hybrid varieties (Zhang *et al*. 2010). In Guangxi, for example, 71 per cent of the maize coverage currently relies on just five inbred lines (Song and Vernooy 2010). As elsewhere in the developing world, farmers are increasingly adopting hybrid seeds, increasing their dependence on high-input cropping systems. Hybrids often do not do well without sufficient doses of chemical inputs. They also require the purchase of new seeds year after year for optimum results. However, agro-ecological and organic agriculture in China has maintained some of the genetic diversity in the country's indigenous maize genebank. Grassroots approaches, such as participatory plant breeding, which involves farmers and local organisations, have attempted to improve crop varieties and farmers' livelihoods. These approaches offer the potential of low carbon, climate-resilient food security, supplying safe and nutritious food whilst also retaining control of agri-food systems (and their associated economic exchanges) at the community level.

5.2 Agro-ecological and sustainable agriculture: politics

As detailed above, State support has been a notable feature of organic and agro-ecological farming, particularly in the early 2000s. However, Thiers (2002: 357) has argued that the predominance of state and market, 'instead of community and ecology', had profound and damaging implications, while direct state intervention may 'overcome some of the public-goods and collective-action problems often associated with organic agriculture'. He concluded that 'conflicts of interest between the state as regulator and as producer erode the consumer trust upon which organic markets rely'. Since these certification bodies are also profit-oriented and state-affiliated organisations 'which cooperate closely with local governments and entrepreneurs', distrust of the certification system is quite high among civil-society groups, such as PEAC, which have tried to popularise green and organic foods, and some are actively 'looking to provide alternatives to the already existing "alternatives"' (Klein 2009: 79). According to Klein, this critique from community-oriented organic groups extends to that of the dominant 'enterprise plus farmer' model for organic production, under which enterprises contract production work out to individual farmers, supply inputs such as seed and organic fertiliser, and reap most of the profits.

Such a critique is quite muted, in fact, when compared to the one arising from the new Rural Reconstruction Movement (RRM,) modelled on a movement of the same name in the 1930s, which has re-emerged as a force since the early 2000s, headed mostly by university academics, public intellectuals, NGOs and some 'para-governmental rural support organisations', to popularise alternative ideas of rural development, provide policy advice and mobilise 'student volunteers for rural support'. From the perspective of the RRM, the Reform Era has brought about 'commodification of agricultural inputs, labour, public goods and technical services, a steady exodus of educated rural youth as migrants to cities, the aging and feminisation of rural producers, fragmentation of familial life, estrangement of social relations within villages, growing rural disparity', and more, '[a] complex of interrelated problems', termed the *san nong* (三农) problems, suggesting 'rural sustainability has been threatened in three dimensions': rural livelihood and its reproduction (*nongmin* 农民, or peasants); the 'coherence of rural society' (*nongcun* 农村, or the countryside); and the 'sustainability of agricultural production' (*nongye* 农业, or agriculture) (Yan and Chen 2013: 964).

As such, the RRM has helped to articulate and promote a politically significant alternative model of agricultural modernisation, particularly through the advocacy of the rural cooperative model as an alternative to the dominant Dragon Head and 'enterprise plus farmer' (公司家农户) models of agriculture. In contrast to dominant discourses that attribute the '*san nong* crisis' to 'rural backwardness and deficiency in modernisation', Wen Tiejun (the most prominent intellectual in the

RRM, formerly Dean of the School of Agriculture and Rural Development at Renmin University in Beijing and now based at Southwest University in Chongqing) argues that the crisis 'has its root in the very dynamics of modernisation'. Another such intellectual, He Huili, argues that the new RRM can build a 'post-capitalist new civilisation that respects farming traditions and values ecological agriculture' (Yan and Chen 2013: 968–9). A critique of GM technologies, although not ubiquitous in the RRM, has also been prevalent in debates and literature associated with the movement and links to discussions of food sovereignty described above.

These are far from mainstream views in China, yet as consolidation and similar reforms have taken place, the number of rural cooperatives have simultaneously mushroomed in China, many practicing organic and ecological agriculture, and some attempting to create new linkages between rural producers and urban consumers. Bishan Commune, in Anhui Province in central China, founded by the artist Ou Ning, for example, has not only become a centre for artistic and cultural events related to the RRM (Walker 2013), but also has seen farmers selling organic produce directly to urban consumers via social media and e-commerce websites (Larson 2014).

Such sales of organic food direct to urban consumers has also been promoted as a model by groups practicing Community Supported Agriculture (CSA) in major cities, including Beijing and Chengdu (Zhang and Mol 2014), promoted particularly by the Hong Kong-based NGO Partnership for Community Development (PCD). While it seems probable that such urban consumers are concerned about the safety and environmental impact of the foods they buy, it is notable that CSA advocates point out the wider political critique at work in such alternative models (including a common 'no GM' label). For participants in CSA, writes one advocate (Yin 2012), 'organic isn't about certification, but the trust, support and sharing involved in simple business transactions', before going on to cite the charismatic Hebei farmer *An Jinlei*, 'As a farmer, I don't like the term 'organic'. It's become a buzzword and lost its meaning. The rich folk in the city drive their cars to the supermarket and buy organic food – they're just worried about their own health. But what are their lifestyles and values, their excessive consumption of resources, doing to the health of the planet?' (Yin 2012)

5.3 Agro-ecological and sustainable agriculture: practices

Research into practices around agro-ecological farming will mean attempting to understand the culturally and socially embedded responses to these developments and innovations of 'producers' and 'users', here including:

- arable farmers (particularly of maize) and their agricultural practices, customs, knowledge of seeds and other aspects of agricultural production, links to buyers in the supply chain, organic or other certification schemes and other quality assurance practices;
- livestock rearers feeding maize to their animals, including any preferences for particular forms of maize and potential avoidance of non-organic due to particular beliefs or forms of market demand and quality assurance practices; food processors, using maize or maize-fed meat as ingredients, and their supply networks and quality assurance practices; and
- end consumers, of maize, meat or processed food, and their preferences for organic, green foods and other forms of certification.

Whilst intellectuals like Wen Tiejun (Moore 2012) and some parts of the Chinese Government (for example through the Outline of the Program for Food and Nutrition Development (2014–2020) have begun to advocate personal reductions in meat consumption, changing the dietary practices of the last of the categories above is a complex challenge. As has been noted in earlier sections, a preoccupation with health and food safety, linked to environmental concerns, has been seen to shape consumer awareness and choices in China. Garnett and Wilkes (2014) cite two international comparative surveys that found 'the environmental motivations of Chinese consumers are quite high', with one finding that '44 per cent of Chinese respondents said they were willing to pay more for products that are good for the environment, a greater percentage than in the US or UK' and the other that food based on 'agricultural systems that use fewer or no chemical inputs, such as those based on ‘green’ or organic approaches [was] seen as safer than those which may rely very heavily on such inputs'. (Garnett and Wilkes 2014: 95) Related to that, while China has seen an overall trend towards higher consumption of meat, the past decade has seen the 'rapid development' of vegetarian catering in Chinese cities (Garnett and Wilkes 2014: 96). Major cities now have many vegetarian restaurants, which often are also organic and have an emphasis on health. Garnett and Wilkes cite the emergence of a 'new vegetarianism [among the] young, urban elite, [a] .holistic response to a nexus of concerns about human health, the environment, animal welfare and the wastefulness of feeding grains to animals', perhaps echoes of those ideas promoted by Simon Chau of Hong Kong’s Green Living movement, who founded the first organic farm in Hong Kong, the Vegetarian Society there and the Green Living Education Foundation (Lou 2014).

6. Programme of work

The final section of this paper outlines our intended approach to the research questions and areas previously outlined, through 'Low Carbon Innovation in China: Prospects, Politics and Practice', an international collaboration between researchers in the UK and at leading institutions in China that aims to facilitate low-carbon transition on a global scale. Applying these questions to both of the two cases described above. We will ask the following questions:

- Are transitions towards more low carbon and sustainable food systems emerging and why? How are they associated with the innovative transgenic and agro-ecological approaches?
- How do the potential transitions in the agri-food system relate to broader processes of decarbonisation?
- What socio-political changes are emerging in China with implications for the changes in the agri-food system, including the social practices around production and consumption of food (especially maize and maize-fed livestock)? What are these implications?
- What lessons does China's approach to innovation for low carbon/sustainable agriculture provide for other countries' industrial policies for (a) low-carbon/ sustainable agri-food transitions, and (b) globally competitive, low-carbon agri-food industries?

Both case studies will be studied using methods that aim to appreciate and to engage with the politics of the potential transitions in question. The basis for this approach is discussed in more detail in the overarching working paper for this project (Tyfield *et al*. 2014a). Drawing from insights offered by 'phronetic' policy research (Flyvberg 2001) and 'participatory' research (Gaventa and Cornwall 2006), we hope, not only to record and report on different framings, but, in a dynamic context, help to cultivate a reflective understanding within the participants themselves, regarding visions, framings and transition pathways. As such, our research is indissolubly both analytical and normative (Leach *et al*. 2007: 7). By 'opening up' policy narratives to reflection and critique from wider perspectives, we hope to contribute to debates and policy processes that result in more environmentally sustainable and socially just outcomes (Leach *et al*. 2010). This impact focus will be enhanced by strategic discussions early in the project cycle to explore and map potential impact pathways, an exercise that has in addition proved useful to the research process in other STEPS Centre projects (Ely and Oxley 2014).

Across the case studies, we will adopt a variant of a 'backward mapping' methodology (Elmore 1980) to compare and contrast differing framings and visions of system transition from innovators, consumers and users back to the visions elucidated in high-level regulatory and policy statements or company strategies. Elmore described 'forward-mapping' as a strategy that 'begins with as clear a statement as possible of the policy-maker's intent, and proceeds through a sequence of increasingly more specific steps to define what is expected of implementers at each level', and ends with a statement, 'again with as much precision as possible, what a satisfactory outcome would be, measured in terms of the original statement of intent'. Traditional implementation studies of this kind thus focus on the extent to which policy framings of technology development and practice are successfully imposed on users (as the targets or subjects of policy and regulation). Conversely, backward-mapping adopts perspectives and practices of users or street-level regulators and users as a starting point, and maps backwards to understand the disjunctures with regard to regulatory and industrial framings at progressively higher levels (Van Zwanenberg *et al.* 2010). Employed in this way, backward-mapping aims to unmask user framings of technologies, the contexts in which they are encountered and the socio-technical practices associated with their use. This allows the analyst to identify inconsistencies, bottlenecks and irreconcilable tensions between the policy framings on the one hand and the user framings on the other.

In particular, this method will be used to compare dominant 'producer' framings (held by government or non-government proponents of transgenic agricultural systems or organic/agro-ecological approaches) with the actual reception and use of the respective innovations by arable and livestock farmers, food processors and consumers. The former will be analysed through semi-structured interviews as well as, for triangulation, discourse analysis of major strategy documents and, where possible, some extended observation. Whilst using these narratives to bound our research site, we will simultaneously research the user framings on the potential agri-food transitions by conducting multi-sited ethnographic research, interviews and focus groups in farming communities and among urban and rural consumers. In the agri-food work package, the project team will aim to interview or engage at least five academic experts, five policy-makers, five companies (domestic and international), five NGOs and at least six focus groups with a minimum size of five users (adopting a stratified random sampling technique as far as possible). In total, there will be at least 50 respondents/ participants.

Tracing the links between these various 'producer' and 'recipient'/'user' worlds will require us to follow people, artefacts, institutions or ideas between multiple sites (Marcus 1995). This will allow us to develop a deeper understanding of the relationships and links between user groups, artefacts and their associated networks, however it also opens up the risk of a never-ending and unwieldy fieldsite, with challenges of focus and prioritisation. Drawing on the experience of other backward-mapping analysts (Ely and Sleeboom-Faulkner forthcoming), therefore, we will bound our study on the basis of policy-makers' statements of intent (in Elmore's words), whilst remaining free to trace links between sites when this illuminates relevant dynamics within the potential transitions under study.

Notwithstanding the differences in scale emphasised above, the two models of low-carbon agri-food innovation studied here, and their associated pathways of change, envisage very different futures for Chinese food security and sovereignty and involve different, possibly conflicting, social constituencies, political actors, institutions and discourses. This conjunction in turn reflects on some of the key questions raised by this study, what the emerging politics, practices and prospects of various approaches to low-carbon innovation in China (from high-tech, centrally managed approaches, to more grassroots groundswells or open-source efforts) might tell us about the country's socio-political context with regard to low-carbon innovation, and what that might suggest about the potential for a transition to a more climate-resilient society in China.

Ultimately, the research should provide insights to innovation studies, political science, practice theory and China studies, all literatures to which we hope to contribute over the coming years. In addition, taking China as an example, it will document and offer lessons around industrial and environmental policy that both meets the political aims of developing an internationally competitive agri-food sector whilst at the same time contributing to food security and the decarbonisation of the agri-food system at the national level. We hope that this analysis will, not only prove relevant to the globally-important challenge of low carbon transitions in China, but also offer insights that can contribute to improved policy processes and decision making in the UK and other countries.

References

Abramovitz, M. (1986) 'Catching up, forging ahead, and falling behind', *Journal of Economic History* XLVI.2: 385–406

Altenburg, T., Schmitz, H. and Stamm, A. (2008) 'Breakthrough China's and India's Transition from Production to Innovation', *World Development* 36.2: 325–344

Altenburg, T. and Pegels, A. (2012) 'Sustainability-oriented innovation systems – managing the green transformation', *Innovation and Development*, 2.1: 5–22

An, B. (2013) 'Cotton and papaya only GM products for commercial use', *China Daily* 16 September

Ansfield, J. (2013) 'Alchemy of a protest: the case of Xiamen PX' in S. Geall (ed.) *China and the Environment: The Green Revolution,* London: Zed Books

Beck, U. (1992) Risk Society: Towards a New Modernity, London: SAGE

Beise, M. (2004) 'Lead markets: country-specific drivers of the global diffusion of innovations', *Research Policy* 33.6–7: 997–1018

Bloomberg News (2013) 'Chinese Anger Over Pollution Becomes Cause of Social Unrest', 6 March 2013

Burney, J. A., Davis, S. J. and Lobell, D.B. (2010) 'Greenhouse gas emission by agricultural intensification', *Proceedings of the National Academy of Sciences* 107.26: 12052–57

Businesswire (2009) 'Origin Agritech Limited Reaches Agreement for Novel Glyphosate-Tolerance Gene, Worldwide Rights for Genetically Modified (GM) Corn, Soybean, Rice, Cotton, and Canola products', http://www.businesswire.com/news/home/20090917005626/en/Origin-Agritech-Limited-Reaches-Agreement-Glyphosate-Tolerance-Gene (29 November 2013)

Byrne, R., Smith, A., Watson, J. and Ockwell, D. (2011) *Energy Pathways in Low-Carbon Development: from Technology Transfer to Socio-Technical Transformation*, STEPS Working Paper 46, Brighton: STEPS Centre

CCICED (China Council for International Cooperation on Environment and Development) (2013) *Media and Public Participation Policies on Promoting China's Green Development*, CCICED Short Report, Beijing: CCICED

China Water Risk (2013) *012 State of Environment Report Review*, http://chinawaterrisk.org/resources/analysis-reviews/2012-state-of-environment-report-review/ (18 December 2013)

Cole, H. S. D., Freeman, C., Jahoda, M. Pavitt, K. L. R. (eds) (1973) *Models of Doom: A Critique of the Limits to Growth*, New York: Universe Books

Cook, S., Conrad, C., Fowlkes, A. L., Mohebbi, M. H. (2011) 'Assessing Google Flu Trends Performance in the United States during the 2009 Influenza Virus A (H1N1) Pandemic', *PLoS ONE* 6.8: e23610

Cui Z. and Yu, D. (2013) 'Gov't, Scientists Struggle to Root Out Opposition to GM Foods', *Caixinonline* 19 December, http://english.caixin.com/2013-12-19/100619487.html

Du, L. and Rachul, C. (2012) 'Chinese newspaper coverage of genetically modified organisms', *BMC Public Health* 12: 326

Elmore, R. (1980) 'Backward Mapping: Implementation Research and Policy Decisions', *Political Science Quarterly* 94.4: 601–616

Ely, A. and Oxley, N. (2014) *STEPS Centre Research: Our Approach to Impact*, STEPS Working Paper 60, Brighton: STEPS Centre

Ely, A. and Scoones, I. (2009) *The Global Redistribution of Innovation: Lessons from China and India*, STEPS Working Paper 22, Brighton: STEPS Centre

Ely A. and Sleeboom-Faulkner, M. (forthcoming) 'Understanding the regulation of medical biotechnologies in diverse settings: tensions and synergies between multi-sited ethnography and 'backward-mapping'', Brighton: Centre for Bionetworking

Elzen, B., Geels, F. W. and Green, K. (eds) (2004) System Innovation and the Transition to Sustainability: Theory, Evidence and Policy, Cheltenham: Edward Elgar

Esty, D. C. and Porter M. (2001) Ranking National Environmental Regulation and Performance: ALeading Indicator Future Competitiveness?', Chapter 2.1 in J. Sachs, J. M. Porter, K. Schwab, J. McArthur, and P. Cornelius, (eds) *Global Competitiveness Report 2001–2*, New York: Oxford University Press

Fang, Z. (2012) 'Fang Zhouzi: Huanjing yumi yu huanjing zhu方舟子:环保玉米与环保猪' (Fang Zhouzi: Environmentally friendly maize and environmentally friendly pigs), *Xinhua Ribao Dianxun,* 20 April

FAO (2012) FAOStat Maize database, http://faostat3.fao.org (28 December 2014)

Fischer, D. (2012) 'The Importance of Being Earnest: The green economy and sustainable development in China', *Asia Policy Brief 2012/02*, Gütersloh: Bertelsmann Stiftung

Flyvbjerg, B. (2001) *Making Social Science Matter: Why Social Inquiry Fails and How It Can Succeed Again,* Cambridge: Cambridge University Press

FORHEAD (Forum on Health, Environment and Development) (2014) *Food Safety in China: A Mapping of Problems, Governance and Research,* FORUM Working Group on Food Safety Report, New York NY: SSRC

Freeman, C. (1996) 'The greening of technology and models of innovation', *Technological Forecasting and Social Change* 53.1: 27–39

GAIN (Global Agricultural Information Network) Report (2009) *China – People's Republic of, Biotechnology*, GAIN Report CH9091, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biotechnology_Beijing_China%20-%20Peoples%20Republic%20of_11-25-2009.pdf (29 September 2014)

Garnett, T. and Wilkes, A. (2014) *Appetite for Change: social, economic and environmental transformations in China's food system*, Oxford: Food Climate Research Network, University of Oxford

Gaventa, J. and Cornwall, A. (2006) Challenging the boundaries of the possible: participation, knowledge and power, IDS Bulletin 37.6: 122–128

Geall, S. and Hilton, I. (2014) 'China: Struggling toward an 'Ecological Civilisation'' in *State of the World 2014: Governing for Sustainability,* Washington DC: Worldwatch Institute

Geall, S. and Pellissery, S. (2012) 'Five Year Plans', in R. C. Anderson, S. Geall and E. N. Anderson (eds) *Berkshire Encyclopedia of Sustainability: China, India, and East and Southeast Asia: Assessing Sustainability,* Great Barrington, MA: Berkshire Publishing

Hand, M. and Shove, E. (2007) 'Condensing Practices: Ways of living with a freezer', *Journal of Consumer Culture* 7.1: 79–104

Herring, R. (2009) 'China, Rice, and GMOs: Navigating the Global Rift on Genetic Engineering', *The Asia-Pacific Journal* 3.2.09, 12 January, http://www.japanfocus.org/-ron-herring/3012

Ho, M. (2013) 'Disappearing rats and dying pigs. Are GMOs to blame?' ISIS Report 5/8/13, http://www.i-sis.org.uk/Disappearing_Rats_Dying_Pigs_Are_GMOs_to_Blame.php (18 December 2013)

Ho, P., Vermeer, E. B. and Zhao, J. H. (2006) 'Biotechnology and Food Safety in China: Consumers' Acceptance or Resistance?' *Development and Change* 37.1: 227–254

Holdaway, J. (2013) 'Environment and Health Research in China: The State of the Field', *The China Quarterly* 214: 255–282

Hornby, L. (2014) 'China scythes grain self-sufficiency policy', *Financial Times,* 11 February

Hu, D., Reardon, T., Rozelle, S., Timmer, P. and Wang, H. (2004) 'The Emergence of Supermarkets with Chinese Characteristics: Challenges and Opportunities for China's Agricultural Development', *Development Policy Review* 22.5: 557–586

Huang, J., Qiu, H., Bai, J. and Pray, C. (2006) 'Awareness, acceptance of and willingness to buy genetically modified foods in Urban China', *Appetite* 46: 144–151

Hvistendahl, M. and Enseink, M. (2012) 'Chinese researchers punished for role in GM rice study', *Science*, ScienceInsider, 12 December, http://news.sciencemag.org/people-events/2012/12/chinese-researchers-punished-role-gm-rice-study

IPCC (2013) 'Summary for Policymakers', in T.F. Stocker, D. Qin, G-K., Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK and New York NY, USA: Cambridge University Press

Jia, H. and Liu, L. (2014) 'Unbalanced progress: the hard road from science popularisation to public engagement with science in China', *Public Understanding of Science* 23.1:32–7

Keeley, J. (2005) 'Interrogating China's Biotech Revolution: Contesting dominant science policy cultures in the risk society' in M. Leach, I. Scoones and B. Wynne *Science and citizens: globalization and the challenge of engagement,* London: Zed Books

Kelly, D. (2014) 'Central-Local Relations: How To Keep A Lid On Debt', *China Economic Quarterly*, March: 55–7

Kern (2011) 'Ideas, institutions, and interests: explaining policy divergence in fostering 'system innovations' towards Sustainability', *Environment and Planning C: Government and Policy* 29: 1116–1134

Klein, J. (2009) 'Creating ethical food consumers? Promoting organic foods in urban Southwest China', *Social Anthropology* 17.1: 74–8

Larson, C. (2014) 'E-Commerce Gives a Lift to China's Rural Farmers', *Bloomberg Businessweek,* 13 February

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C. and Olsson, P. (2012) 'Transforming Innovation for Sustainability', *Ecology and Society* 17.2: 11

Leach, M., Scoones, I. and Stirling, A. (2007) *Pathways to Sustainability: an overview of the STEPS Centre approach*, STEPS Approach Paper, Brighton: STEPS Centre

— (2010) 'Dynamic sustainabilities: Technology, Environment, Social Justice', London: EarthScan

Lema, R. and Lema, A. (2012) 'Technology transfer? The rise of China and India in green technology sectors', *Innovation and Development* 2.1: 23–44

Levitt, T. (2014) *Who will feed China's pigs… And why it matters to us and the planet*, chinadialogue 18 August, https://www.chinadialogue.net/article/show/single/en/7226-Who-will-feed-China-s-pigs- (29 August 2014)

Li, J., Lammerts van Bueren, E. ,Jiggins, J. and Leeuwis, C. (2012) 'Farmers' adoption of maize (Zea mays L.) hybrids and the persistence of landraces in Southwest China: implications for policy and breeding, *Genetic Resources and Crop Evolution*, 59.6: 1147–1160

Liu, Q. (2014) 'China's revised environmental protection law 'better than expected'', *chinadialogue* 23 April, https://www.chinadialogue.net/blog/6935-China-s-revised-environmental-protection-law-better-than-expected-/en

Lockwood, M. (2013) Governance, Innovation and the Transition to a Sustainable Energy System: Perspectives from Economic Theory, EPG Working Paper 1305, Exeter: Exeter Energy Policy Group

Lou, L. (2014) 'Hong Kong's vegan guru, *chinadialogue,* 16 April, https://www.chinadialogue.net/books/6910-Hong-Kong-s-vegan-guru/en

Ma, D. and Adams, W. (2013) *In Line Behind a Billion People: Will Scarcity Stop China from Winning the Global Economic Race?* Upper Saddle River NJ: Pearson Education US

Marcus, G. E. (1995) 'Ethnography in/of the world system: The emergence of multi-sited ethnography, *Annual Review of Anthropology* 24: 95–117

Mazzucato, M. (2013) The Entrepreneurial State: debunking public vs. private sector myths, London: Anthem Press

Meadowcroft, J. (2009) 'What about the politics? Sustainable development, transition management, and long term energy transitions', *Policy Sciences* 42.4: 323–340

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens III, W. W. (1972) *The Limits to Growth: a report for the Club of Rome's project on the predicament o mankind*, New York NY, Universe Books

Meng, S. (2012) 'An insight into the green vocabulary of the Chinese communist party', c*hinadialogue* 15 November https://www.chinadialogue.net/article/show/single/en/5339

MEP (Ministry of Environmental Protection) (2013) *State of Environment Report 2012* [Chinese] http://www.mep.gov.cn/gkml/hbb/qt/201306/W020130604382172090857.pdf (18 December 2013)

Ministry of Agriculture (2014) 'Transgenic breeding biosafety certificate (2014), Number 3', December 11

Moore, M. (2012) 'China now eats twice as much meat as the United States', *The Telegraph* 12 October, http://www.telegraph.co.uk/news/worldnews/asia/china/9605048/China-now-eats-twice-as-much-meat-as-the-United-States.html (29 August 2014)

Normile, D. (2014) 'China pulls plug on genetically modified rice and corn', *Science Insider* 20 August 2014, http://news.sciencemag.org/asiapacific/2014/08/china-pulls-plug-genetically-modified-rice-and-corn (28 August 2014)

Ockwell, D. G., Whitmarsh, L. and O'Neill, S. (2009) 'Reorienting climate change communication for effective mitigation - forcing people to be green or fostering grass-roots engagement?' *Science Communication* 30: 305–327

Origin Agritech (2013) 'Origin Agritech Limited Reports Unaudited Financial Results for the Year Ended September 30, 2012', http://www.marketwatch.com/story/origin-agritech-limited-reports-unaudited-financial-results-for-the-year-ended-september-30-2012-2013-01-08 (18 December 2013)

– (2008) 'GM Phytase Corn Saves Feed Costs and Improves the Environment', http://gmopundit.blogspot.co.uk/2008/02/gm-phytase-corn-saves-feed-costs-and.html (18 December 2013)

Paull, J. (2007) 'China's organic revolution', *Journal of Organic Systems* 2.1: 1–11

Porter, M. E. and van der Linde, C. (1995) 'Toward a New Conception of the Environment-Competitiveness Relationship', *The Journal of Economic Perspectives* 9.4: 97–118

PRS Newswire (2013) 'Origin Agritech Limited Reports Unaudited Financial Results for the Year Ended 30 September 2012', 8 January 2013

Qiu, J. (2010) 'Phosphate fertiliser warning for China', *Nature,* 29 September

Qu J. (2012) 'The Project System: A New Form of State Governance', *Social Sciences in China,* 33.4: 28–47

Quitzow, R., Walz, R., Köhler, J. and Rennings, K. (2014) 'The concept of 'lead markets' revisited: Contribution to environmental innovation theory', *Environmental Innovation and Societal Transitions* 10: 4–19

Reardon, T., Berdegué, J. and Timmer, P. (2005) 'Supermarketization of the 'Emerging Markets' of the Pacific Rim: Development and Trade Implications', *Journal of Food Distribution Research* 36.1: 3–12

Rennings, K. (2000) 'Redefining innovation - eco-innovation research and the contribution from ecological economics', *Ecological Economics* 32.2: 319–332

Rockström, J., Steffen, W., Noone, K., ersson, A., Chapin III, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., Van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. A. (2009) 'A safe operating space for humanity', *Nature* 461.7263: 472–475

SAIN Online (2011) UK-China Project on 'Improved Nutrient Management in Agriculture – a Key Contribution to the Low Carbon Economy', UK-China Sustainable Agriculture Innovation Network, http://www.sainonline.org/SAIN-website(English)/pages/Projects/lowcarbon.html

Scally, P. (2014) 'Yunnan's organic farming pioneer', c*hinadialogue* 20 March https://www.chinadialogue.net/books/6839-Yunnan-s-organic-farming-pioneer-/en

Schatzki, T., Knorr Cetina, K. and von Savigny, E. (eds) (2001) *The Practice Turn in Contemporary Theory*, London: Routledge

Schmitz, H. (2013) 'How does the global power shift affect the low carbon transformation?' Brighton: Institute of Development Studies

Chen, W. (2009) 'China makes 'landmark' GM crop approval', SciDev.Net, 17 December 2009, http://www.scidev.net/global/biotechnology/news/china-makes-landmark-gm-food-crop-approval.html (29 November 2013)

Schneider, M. and S. Sharma (2014) 'China's Pork Miracle? Agribusiness and Development in China's Pork Industry', Minneapolis MN: Institute for Agriculture and Trade Policy

Shapiro, J. (2001) *Mao's War Against Nature: Politics and the Environment in Revolutionary China*, Cambridge: Cambridge University Press

Shove, E. and Walker, G. (2010) 'Governing transitions in the sustainability of everyday life', *Research Policy* 39.4: 471–476

Smith, A., F. Kern, R. Raven and B. Verhees (2014) 'Spaces for sustainable innovation: Solar photovoltaic electricity in the UK', *Technological Forecasting and Social Change* 81: 115–130

Song, Y. and Vernooy, R. (eds) (2010) *Seeds and synergies: innovating rural development in China*, Rugby and Ottawa: Practical Action Publishing and IDRC

Southerton, D., Díaz-Méndez, C. and Warde, A. (2011) 'Behavioural Change and the Temporal Ordering of Eating Practices: A UK–Spain Comparison', *International Journal of Sociology of Agriculture and Food* 19.1: 19–36

Spaargaren, G., Van Vliet, B. J. M., Van de Horst, H. M., Naus, J. (2014) 'Smart energy practices : examining how householders shape – and are shaped by – smart energy systems: informational govenance', Wageningen: Wageningen University, https://www.wageningenur.nl/en/Publication-details.htm?publicationId=publication-way-343534333438 (17 November 2014)

Stone, R. (2011a) 'On Lake Taihu, China Moves To Battle Massive Algae Blooms', *Yale Environment 360*, New Haven CT: Yale School of Foresty and Environmental Studies

Stone, R. (2011b) 'Activists Go on Warpath Against Transgenic Crops—and Scientists', *Science* 331.6020: 1000–1001

Suttmeier, R. P. (2008) 'The 'Sixth Modernisation''? China, Safety and the Management of Risks,' *Asia Policy* 13: 129–46

The Economist (2013) 'Food fight: A fierce public debate over GM food exposes concerns about America, 14 December 2013

Thiers, P. (2002) 'From grassroots movement to state-coordinated market strategy: the transformation of organic agriculture in China', *Environment and Planning C: Government and Policy* 20: 357–373

Tian F. (2014) 'Xiangmu zhi de zhili luoji 项目制的治理逻辑' ('Governance logic of the project system'), *Xin chanjing,* 1 February

Tyfield, D., Ely, A., Urban, F., Geall, S., Zuev, D. and Urry, J. (2014a) *Low Carbon Innovation in China: Prospects, Politics and Practices*, STEPS Working Paper 69, Brighton: STEPS Centre

Tyfield, D., Zuev, D., Ping, L. and Urry, J. (2014b) *Low Carbon innovation in Chinese Urban Mobility: Prospects, Politics and Practices*, STEPS Working Paper 71, Brighton: STEPS Centre

Urban, F. and Geall, S. (2014) *Pathways Towards Renewable Energy in China: Prospects, Politics and Practices*, STEPS Working Paper 70, Brighton: STEPS Centre

Van Zwanenberg, P., Ely, A. and Smith, A. (2011) Regulating Technology: International Harmonization and Local Realities, London: Earthscan

Vernooy, R. (2012) 'For Food Security, China Tries an Alternative to Industrial Agriculture', *Solutions* 3.1: 62–69

Verhees, B., Raven, R., Veraart, F., Smith, A. and Kern, F. (2013) 'The development of solar PV in the Netherlands: A case of survival in unfriendly contexts', *Renewable and Sustainable Energy Reviews* 19: 275–289

Wang, Y. (2014a) 'Polluted farmland leads to Chinese food security fears', *chinadialogue,* 7 January, https://www.chinadialogue.net/article/show/single/en/6636-Polluted-farmland-leads-to-Chinese-food-security-fears

Wang, Y. (2014b) 'Almost one-fifth of our arable land is polluted, admit Chinese officials', 17 April, https://www.chinadialogue.net/blog/6921-Almost-one-fifth-of-our-arable-land-is-polluted-admit-Chinese-officials/en

Warde, A. (2005) 'Consumption and Theories of Practice', *Journal of Consumer Culture* 5.2: 131–153

Watson, J. and Sauter, R. (2011) 'Sustainable innovation through Technological Leapfrogging: A Review of the Evidence', *International Journal of Technology and Globalisation* 5.3/4: 170–189

Walker, B. (2013) 'Stemming the tide of urban-rural migration', *chinadialogue* 22 August, https://www.chinadialogue.net/books/6312-Stemming-the-tide-of-rural-urban-migration/en

Wu, J. and Han, X. (2012) 'Catalogue of a crisis', *chinadialogue,* 28 May https://www.chinadialogue.net/article/show/single/en/4946-Catalogue-of-a-crisis

Xinhua (2014) 'No.1 Central Document targets China's rural reform', *Xinhuanet,* 19 January, http://news.xinhuanet.com/english/china/2014-01/19/c_133057121.htm

Yan, H. and Chen, Y. (2013) 'Debating the rural cooperative movement in China, the past and the present', *The Journal of Peasant Studies* 40.6: 955–981

Yan, Y. (2012) 'Food safety and social risk in China', *The Journal of Asian Studies* 71.3: 705–729

Yin, C. (2012) 'We're all farmers now', *chinadialogue,* 29 May https://www.chinadialogue.net/article/show/single/en/4944-We-re-all-farmers-now

Zhang, C. (2010) 'Zhuanjiyin zhisuanmei yumi zai ditanjingjishidai dayoukewei' 转基因植酸酶玉米在低碳经济时代大有可为 ('GM phytase maize has bright prospects in the low-carbon economic era'), *People's Daily* 18 March

Zhang, L. and Mol, A. (2014) 'Consumer trust and alternative food supply: a case study from Beijing, China', Conference paper at Global Research Forum on Sustainable Consumption and Production, Fudan University, 8–11 June 2014

Zhang, S., Huang, K. and Song, Y. (2010) 'Maize and the formal agricultural research and development system: evolution, challenges, and alternatives', in *Seeds and Synergies: Innovation in Rural Development in China*, Y. Song and R. Vernooy (eds) Rugby and Ottawa: Practical Action Publishing and IDRC

Zhang, W., Dou, Z. X., He, P., Ju, X. T., Powlson, D., Chadwick, D., Norse, D., Lu, Y. L., Zhang, Y., Wu, L., Chen, X. P., Cassman, K. G. and Zhang, F., S. (2013) 'New technologies reduce greenhouse-gas emissions from nitrogenous fertilizer in China' *Proceedings of the National Academy of Sciences USA* 110: 8375–8380

Zhang, Y. (2013) 'Celebrity feud ramps up GM food debate', *Global Times,* 26 December

Zheng, C., Jie, Y., Xia, Z., and Spence, W. (2013) 'Monsanto's Cautious China Strategy', *Caixin online* 24 December 2013, http://english.caixin.com/2013-12-24/100621301.html?p3 (29 August 2014)

Zi, Y. (2010) 'Opportunities and risks of genetically modified crops' in D. Yang (ed) *The China Environment Yearbook, Volume 4: Tragedy and Hope*, Leiden: Brill