PATHWAYS TO SUSTAINABILITY

GOVERNING AGRICULTURAL SUSTAINABILITY

Global lessons from GM crops

Edited by Phil Macnaghten and Susana Carro-Ripalda

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GOVERNING AGRICULTURAL SUSTAINABILITY

Although genetically modified (GM) crops are seen by their advocates as a key component of the future of world agriculture and as part of the solution to world poverty and hunger, their uptake has not been smooth nor universal: they have been marred by controversy and all too commonly their regulation has been challenged as inadequate, even biased.

This book aims to understand these dynamics, examining the impacts of GM crops in diverse contexts and their potentials to contribute to sustainable agricultural futures. Part I draws on research from three global 'rising powers' – Brazil, India and Mexico – exploring the views of scientists, farmers and publics. Using a diverse array of ethnographic and qualitative methodologies, the book examines the dynamics that have underpinned the controversy in three diverse geopolitical contexts, the manner in which dominant institutional framings have been closely aligned with the interests of powerful elites, and the multiple ways in which these have been resisted through local, symbolic and material practices. Part II follows this analysis with a series of reflective commentary pieces from 11 leading academics in the social and life sciences, developing new thinking on how to develop a governance framework for the responsible innovation of agricultural GM technologies.

This innovative book offers new insights for researchers and postgraduates in science and technology studies, agro-ecology and environmental studies, development studies, anthropology, human geography, sociology, political science, public administration, Latin American studies and Asian studies.

Phil Macnaghten is Professor of Technology and International Development at Wageningen University in The Netherlands. He was Professor of Geography at Durham University (UK), and Founder Director of Durham University's Institute of Hazard and Risk Research. He coordinated the GMFuturos research project.

Susana Carro-Ripalda is a social anthropologist, Honorary Research Fellow at Durham University, and currently Visiting Researcher at the Universidad del País Vasco, Spain. She was Senior Research Fellow and GMFuturos Project Manager in the Department of Anthropology at Durham University, and has lectured at the universities of Durham, Glasgow and Edinburgh.

Pathways to Sustainability Series

This book series addresses core challenges around linking science and technology and environmental sustainability with poverty reduction and social justice. It is based on the work of the Social, Technological and Environmental Pathways to Sustainability (STEPS) Centre, a major investment of the UK Economic and Social Research Council (ESRC). The STEPS Centre brings together researchers at the Institute of Development Studies (IDS) and SPRU (Science and Technology Policy Research) at the University of Sussex with a set of partner institutions in Africa, Asia and Latin America.

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'Distilling a decade of research at UK institutions, this wide-ranging collection wisely shifts our attention from the disputed technical properties of GM crops to the kinds of politics needed to accommodate GM agriculture on a global scale. If one book could prod the GM debate out of its current sterile stalemate then this would be it.'
Sheila Jasanoff, Pforzheimer Professor of Science and Technology Studies, Harvard Kennedy School, USA

'Can GM crops feed the world? Such an apparently straightforward question is revealed in this book instead as a lens on the daunting intersections of technological advance, globalization, political and economic power, and cultural identity. Through the subtle studies in this volume, GM crops become nothing less than a powerful and poignant metaphor for whatever it is that seems to have replaced the ruthless innocence of modernity.'
Daniel Sarewitz, Professor of Science and Society and Co-Founder and Co-Director of the Consortium for Science, Policy & Outcomes (CSPO) at Arizona State University, USA

'A fascinating and unique book addressing the development and deployment of GM crops in a wide variety of different agroecosystems and countries. It steers between the unhelpful dichotomies of the past, and shows that GM agriculture is neither inevitably a good thing or a bad thing: it depends on the social, ecological and political circumstances.'
Jules Pretty OBE, Deputy Vice-Chancellor and Professor of Environment & Society at the University of Essex, UK

'The quest to document, to make sense of and to advocate solutions to the continuing controversies surrounding genetically modified crops has spawned a large library of literature. This edited but integrated volume both contributes to that discussion and extends it in new directions. Rather than starting with an analysis of the claims and counterclaims for GM crops, it asks why such crops have not been viewed as a universal public good. In asking that question, it moves beyond the endless polemics and identifies how and under what conditions GM crops might be widely accepted. Moreover, by focusing on Mexico, Brazil and India – three nations where empirical research has been limited – the authors show how these technologies are framed differently in different settings. In so doing the authors illustrate the limits of both the information deficit model and formal risk analysis as means for resolving controversies. In their place, the authors present an alternative pluralistic and inclusive model for decision-making – a model that just might move us toward better governance of technological change. Scholars and decision-makers concerned about public controversies surrounding technological change would do well to read this volume.'
Lawrence Busch, University Distinguished Professor at Michigan State University, USA

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The GMFuturos project ran from February 2012 to November 2014, led by Durham University. We are grateful to the Durham team and associated Advisory Board, and the unique interdisciplinary atmosphere and openness cultivated at Durham that made it possible. Particular individuals we would like to thank include Brian Black, Joanildo Burity, Brett Cherry, Yulia Egorova, Penny Harvey, Keith Lindsey, Tom McLeish, Michael Northcott, Bob Simpson and Brian Wynne.

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ABBREVIATIONS AND ACRONYMS

ABLE	Association of Biotechnology Led Enterprises (India)
ABRANGE	Brazilian Association of Farmers of Non-Genetically Modified Crops
ACRE	Advisory Committee on Releases to the Environment (UK)
AEBC	Agriculture and Environment Biotechnology Commission (UK)
AGRECO	Serra Geral Hillsides Ecological Farmers Association
AIBA	All India Biotech Association
AIKS	All India Kissan Sabha
AIRR	anticipation–inclusion–reflexivity–responsiveness
APACO	Association of Western Santa Catarina Small Farmers (Brazil)
AS-PTA	Family Agriculture and Agroecology Organisation (Brazil)
BBSRC	Biotechnology and Biological Sciences Research Council (UK)
BIS	Department for Business, Innovation and Skills (UK)
BRAI	Biotechnology Regulatory Authority of India
BSE	Bovine Spongiform Encephalopathy
Bt	*Bacillus thuringiensis* – a soil-dwelling bacterium, commonly used as a biological pesticide, and whose genes have been introduced through techniques of genetic modification to produce insect-resistant GM crops
CAPA	Small Farmer Support Centre (Brazil)
CECCAM	Centre for Studies for Change in the Mexican Countryside
CESAGEN	ESRC Centre for Economic and Social Aspects of Genomics (UK)
CGIAR	Consultative Group on International Agricultural Research
CIB	Council for Information on Biotechnology (Brazil)
CIBIOGEN	Inter-Ministerial Commission on Biosecurity and Genetically Modified Organisms (Mexico)

CII	Confederation of Indian Industry
CIMMYT	International Maize and Wheat Improvement Centre
CJD	Creutzfeldt–Jakob disease
CNBA	National Agricultural Biosafety Committee (Mexico)
CNBS	National Biosafety Council (Brazil)
CNPSO	National Centre for Soya Research – Embrapa Soja (Brazil)
CONABIO	National Biodiversity Commission (Mexico)
CONANP	National Commission for Protected Natural Areas (Mexico)
CONSEA	National Council on Food and Nutrition Security (Brazil)
CROPSAP	Crop Pest Surveillance and Advisory Project (India)
CTNBio	National Technical Committee on Biosafety (Brazil)
DBT	Department of Biotechnology (India)
DDS	Deccan Development Society (India)
Defra	Department for Environment, Food & Rural Affairs (UK)
DfID	Department for International Development (UK)
DGSV	General Directorate of Plant Health (Mexico)
EASAC	European Academies Science Advisory Council
EFSA	European Food Standards Agency
EGENIS	ESRC Centre for the Study of Life Sciences (UK)
EIA	environment impact assessment
EMBRAPA	Brazilian Corporation of Agricultural Research
EPA	US Environmental Protection Agency
EPAGRI	the rural extension agency of Santa Catarina state government (Brazil)
ESRC	Economic and Social Research Council (UK)
FAO	Food and Agriculture Organization of the United Nations
FDA	US Food and Drug Administration
FETRAF	Federation of Workers in Family Agriculture in the state of Santa Catarina (Brazil)
FICCI	Federation of Indian Chambers of Commerce and Industry
GATT	General Agreement on Tariffs and Trade
GEAC	Genetic Engineering Approval Committee (India)
GM	genetically modified
GMOs	genetically modified organisms
HT	herbicide tolerant
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
IBC	Institutional Biosafety Committee (India)
ICAR	Indian Council of Agricultural Research
ICGEB	International Centre for Genetics and Biotechnology
IDEC	Brazilian Consumer Defence Institute
IMF	International Monetary Fund

INNOGEN	ESRC Centre for Social and Economic Research on Innovation in Genomics (UK)
IPR	intellectual property rights
IR	insect resistant
IRRI	International Rice Research Initiative
ISAAA	International Service for the Acquisition of Agri-biotech Applications
KRRS	Karnataka State Farmers Association
Langebio	National Laboratory of Genomics for Biodiversity in Guanajuato (Mexico)
MAPA	Ministry of Agriculture, Livestock and Food Supply (Brazil)
MDA	Ministry of Agrarian Development (Brazil)
MMA	Ministry of the Environment (Brazil)
MMB	Mahyco Monsanto Biotech (India)
MST	Landless Workers Movement (Brazil)
NAFTA	North American Free Trade Agreement
NAIP	National Agricultural Innovation Project (India)
NEAD	Nucleus of Agrarian Studies and Rural Development (Brazil)
NGO	non-governmental organisation
NIMBY	not in my back yard
NISTADS	National Institute of Science, Technology and Development Studies (India)
NSKE	neem seed kernel extract
OAGEBA	Office of Agricultural Genetic Engineering Biosafety Administration (China)
PPVFR	Protection of Plant Varieties and Farmers Rights Act (India)
PRI	Institutional Revolutionary Party (Mexico)
PROCON	Bureau of Consumer Protection (Brazil)
PSRE	public-sector research establishments
PT	Workers Party (Brazil)
PUS	public understanding of science
RCGM	Review Committee on Genetic Manipulation (India)
RI	responsible innovation
RR	Roundup Ready
S&T	science and technology
SAGARPA	Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (Mexico)
SALUD	Department of Health (Mexico)
SBPC	Brazilian Society for the Progress of Science
SEMARNAT	Secretariat of Environment and Natural Resources (Mexico)
SHG	self-help group
STEPS	Social, Technological and Environmental Pathways to Sustainability (a UK research centre)
STS	science and technology studies

TEC	Technical Experts Committee (India)
TNC	transnational corporation
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UFSC	Federal University of Santa Catarina (Brazil)
UNAM	National Autonomous University of Mexico
USDA	US Department of Agriculture
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

CONTRIBUTORS

Patricia Artía was Research Assistant for the GMFuturos project (Mexico case study), affiliated to the Centro de Investigaciones en Geografía Ambiental, National Autonomous University of Mexico (UNAM), Mexico.

Marta Astier is Associate Professor, Centro de Investigaciones en Geografía Ambiental, National Autonomous University of Mexico (UNAM), Mexico.

Joanildo Burity is Director, School of Postgraduate Studies and Professional Development, Fundação Joaquim Nabuco, Brazil.

Susana Carro-Ripalda is Senior Research Fellow, Department of Anthropology, Durham University, UK.

Ian Crute, CBE was Chief Scientist, Agriculture and Horticulture Development Board, UK.

Yulia Egorova is Senior Lecturer, Department of Anthropology, Durham University, UK.

Adrian Ely is Senior Lecturer at SPRU – Science Policy Research Unit, and Deputy Director of the ESRC STEPS Centre, University of Sussex, UK.

Julia Guivant is Professor at the Department of Sociology and Political Science, Federal University of Santa Catarina (UFSC), Brazil and coordinator of the Institute for Research on Risk and Sustainability (IRIS).

Penny Harvey is Professor of Social Anthropology, School of Social Sciences, University of Manchester, UK.

Les Levidow is Senior Research Fellow at Development Policy and Practice Department, The Open University, UK.

Keith Lindsey is Professor of Plant Molecular Biology, School of Biological and Biomedical Sciences, Durham University, UK.

Phil Macnaghten is Professor of Technology and International Development, Knowledge Technology and Innovation Group, Wageningen University, The Netherlands.

Kamminthang Mantuong was Research Assistant for the GMFuturos project (India case study).

Tom McLeish, FRS is Professor of Physics, Durham University, UK.

Michael Northcott is Professor of Ethics, School of Divinity, University of Edinburgh.

Judith Petts, CBE is Pro-Vice-Chancellor (Research and Enterprise), University of Southampton, UK.

Rajeswari Raina is a researcher at the National Institute of Science, Technology and Development Studies NISTADS – CSIR, India.

Bob Simpson is Professor of Anthropology, Durham University, UK.

PART I
Researching GM crops

In Part I we set out the findings of the GMFuturos research. In Chapter 1 we set out the context of the research, including our conceptual approach. We explain how the project emerged as a response to a John Templeton Foundation call, 'Can GM crops feed the world?'. Following an account of the historical context in which GM crop technologies were developed, the chapter proceeds by setting out our analytical approach and how it was informed by debates in five intersecting literatures: on science and publics, on extant analyses of the GM controversy, on emerging frameworks on responsible innovation, on literatures on pathways to sustainability, and on culture and forms of life. The chapter concludes by setting out the specifics of the research methodologies and how they were applied to three case study areas: to debates on GM maize in Mexico, GM soya in Brazil and GM cotton in India.

In Chapter 2 we set out key findings from the Mexico case study. These include a review of the debate on GM crops in Mexico, ethnographic fieldwork research with rural actors from the Pátzcuaro Lake area of the state of Michoacán, survey and interview research with a variety of local stakeholders involved in the debate on GM agriculture, a laboratory ethnography conducted at the National Laboratory of Genomics for Biodiversity in Guanajuato (Langebio), focus group research with urban publics on Mexican responses to GM crops and foods undertaken in Morelia, and a deliberative workshop conducted with a range of national stakeholders in Mexico City. We find that the debate on GM maize has been deeply controversial and culturally resonant, and that decisions by regulatory bodies have been seen as compromised and lacking in transparency. We find that smallholder farmers retain strong and enduring relations around maize agriculture and that the prospect of GM maize is seen as an intrusion on traditional practices. We find that laboratory scientists are divided on the use of genetic modification technologies on the maize genome. And we identify a general negative reaction to

GM crops and foods among Mexican urban publics, reflecting deep-seated patterns of mistrust in the Mexican government, and their apparent collusion with large corporations.

In Chapter 3 we set out key findings from the Brazil case study. These include a review of the debate on GM crops in Brazil, ethnographic fieldwork research with rural actors from the southern state of Santa Catarina, survey and interview research with a variety of local stakeholders involved in the debate on GM agriculture, a laboratory ethnography conducted at the soya research division (CNPSO) of the state-owned agricultural research organisation Embrapa, focus group research with urban publics on Brazilian responses to GM crops and foods, and a deliberative workshop conducted with a range of national stakeholders. We identify why the debate bred so much polemic up until 2005, and the factors that contributed to the widespread adoption and take-up of GM crops in Brazil since 2005. We then identify through ethnographic research the various ways in which GM crop technologies have been adopted into local agricultural practices, where we find evidence of a conflict between farmers and technical experts from the seed companies, each blaming each other for the growing problem of weed resistance to glyphosate. We find clear and unqualified optimism among scientists on the role of GM crop technologies, with little evidence of a structured and sustained debate with wider society. Finally, we find that Brazilian publics adopt negative views to GM crops and foods (although trusting in the expert systems), principally because the technology is seen as benefit the producer (not the consumer) and because they had not been consulted or clearly informed.

In Chapter 4 we set out key findings from the India case study. These include a review of the debate on GM crops in India, ethnographic fieldwork research with rural actors in the Kalahandi district of western Odisha, survey and interview research with a variety of local stakeholders involved in the debate on GM agriculture, a laboratory ethnography conducted at the New Delhi branch of the International Centre for Genetics and Biotechnology (ICGEB), focus group research with urban and rural publics on Indian responses to GM crops and foods, and a deliberative workshop conducted with a range of national stakeholders in New Delhi. We find that the debate on GM crops has been mired in controversy, culminating in the 2013 ten-year moratorium on GM crops, including field trials. We find evidence of widespread adoption of GM cotton, but also of 'lock-in' to the technology with indigenous seeds no longer so available. We find that scientists whose work we observed were opposed to the moratorium and constructed and perceived the position of anti-GM actors as 'ignorant' or aimed at 'publicity' seeking. And we identify (again) largely negative views from Indian publics to GM crops and foods, with trust once more being a critical dimension.

In Chapter 5 we compare responses to GM crops in Mexico, Brazil and India. We find that in all three cases, the technical regulatory bodies charged with approvals for the release of GMOs had not provided 'authoritative governance', with decisions made by approval committees commonly rejected by institutional and other stakeholders. We then offer a typology aimed at explaining why the controversy surrounding GM crops had taken different forms in different national settings. Factors that were seen to be relevant in structuring the controversy included the perceived authority of the regulatory agencies, the cultural resonance of the crops in question, the level of intensity of protest movements, the extent to which GM can become represented as the symbol of wider struggle, and the degree of sustained effort by institutional actors to engage the public. We then compare the field ethnographies, where we compare the symbolic resonance of the crop in question and where we further analyse the dynamics of blame between actors in relation to the increasing prevalence of glyphosate-resistant weed species and of pest resistance in *Bt* cotton. Comparing the laboratory ethnographies, we find that the research culture across the three sites was lacking in 'reflexivity' and 'inclusiveness'. Comparing the public focus group research, we find little public enthusiasm for GM crops and foods, including a hardening of response as the discussions matured.

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RESEARCHING GM CROPS IN A GLOBAL CONTEXT

Phil Macnaghten, Susana Carro-Ripalda and Joanildo Burity

> The limits of your language are the limits of your world.
>
> *Ludwig Wittgenstein,* Tractatus Logico-Philosophicus *5.6*

Can GM crops help to feed the world?

'Can GM crops help to feed the world?' This is the question that structured a recent call for research from the John Templeton Foundation, a philanthropic trust that specialises in encouraging new forms of dialogue between natural and social scientists and the wider humanities. It is a timely question. With world population expected to exceed 9 billion by 2050, with hunger and chronic malnutrition still afflicting over 800 million people, with increasing per capita incomes, with a growing demand for food globally including meat and dairy products, with the need to protect land for biodiversity and ecosystem services, with the mounting threats associated with climate change and the likely increased scarcity of water and land, with large scale export-led agriculture pushing smallholder farmers and rural wage workers towards urban areas and with associated and intensified rural conflicts and impacts on traditional forms of life, it is unsurprising that food security is fast becoming recognised as one of this century's most critical challenges. These kinds of questions pose very significant challenges for agriculture, including, how to meet this century's demand for food, feed, fibre and fuel on an area of land that is unlikely to increase in the future and in a manner that is just, socially inclusive and mindful of its overall environmental impacts. Or, as a recent report from the Royal Society put the issue, we need to establish how we can 'reap the benefits' from the 'sustainable intensification of global agriculture' (Royal Society 2009).

Undoubtedly, novel science and technology have a role to play in meeting these challenges. Without radical advances, particularly at the molecular level, it is hard to imagine at least within current epistemic frameworks and cultures how yields can be increased without adverse environmental impact or the cultivation of new land. Novel research methods have, so it is commonly claimed, the potential to contribute to food production through forms of genetic improvement, including the genetic modification (GM) of crops that have been modified to introduce new and desirable traits. However, as the John Templeton Foundation framed the issue, 'although primary scientific research in GM crops is well funded by government, industry, and the philanthropic sector, investigation of the optimal practices and policies for implementing GM technology has received much less attention and support' (John Templeton Foundation 2011).

In 2011, a group of anthropologists, human geographers, philosophers, physicists, plant scientists, political scientists and theologians at Durham University in the UK met to consider a response to the John Templeton Foundation call. For the plant scientist (Keith Lindsey), who at the time was a member of the UK's Advisory Committee on Releases to the Environment (ACRE), the regulatory body charged with providing statutory advice to ministers on the risks to human health and the environment from the release of genetically modified organisms (GMOs), the call offered an opportunity for research that would help him understand why society appeared to be so resistant to GM crops when clearly they offered the potential for long-term advantage. For the physicist and science/theology writer (Tom McLeish), who was also at the time Pro-Vice-Chancellor for Research, the call offered an opportunity for interdisciplinary research across the three faculties of the university as well as the opportunity to add to current scientific debate on GMOs through a deeper analysis at the level of culture and religion. For the anthropologists (Susana Carro-Ripalda and Yulia Egorova), the call opened the path to research that would highlight how GM crops were being embedded (or not) in local social, cultural and agricultural practices and how these were impacting particularly on the lives and livelihoods of smallholder farming communities. For the political scientist and religious studies specialist (Joanildo Burity), the call offered an opportunity for experimentation in deliberative methodology and for reflecting on how cultural and religious interpretations met the scientific challenge, to explore whether it was possible for stakeholders to engage in constructive dialogue on an issue so mired in polemic and mutual misunderstanding. While for the science and technology studies scholar (Phil Macnaghten), who was also a specialist in the governance of emerging technologies, the call offered an opportunity to test a qualitative methodology aimed at understanding the factors that shape how lay people perceive GM crop technologies in non-Western settings, including in situations where people are unfamiliar with the technology and its products.

Collectively, this broad-based interdisciplinary group of scholars decided to invert the question posed by the John Templeton Foundation call – 'Can GM crops help to feed the world?' While a timely question, it was considered nevertheless neither as the correct question nor indeed as the most profitable way to structure a debate around agricultural sustainability. Our inversion ran as follows: 'Unless we examine why GM crops have not been universally accepted as a public good, we will fail to understand the conditions under which GM crops can help to feed the world'. Our starting point thus began with local experience rather than with global imperative, with the dynamics of GM crops as understood and embedded in local practices rather than with a technology that requires optimal practices and policies to be successfully implemented. This attempt to reconfigure the debate was not merely academic. It was arguably highly necessary given that agricultural GM technologies have been controversial not just in the UK and Europe but internationally. Over the last two decades, the promotion and regulation of GM crops have precipitated acute political and scientific controversy arguably on a scale without precedent in modern times, resulting in substantial disruption to some of the world's largest companies and to the plans of incumbent governments. Unless we understand why the issue is not settled and why the issue continues to evade policy resolution, attempts aimed at enhanced genetic improvement of crops risk generating further controversy, misunderstanding and polemic.

In this volume we offer a new way of configuring the debate on GM crops and its potential to contribute to agricultural sustainability. At the core of the volume are three empirical chapters (Chapters 2, 3 and 4 respectively) of the GMFuturos research, each looking at how the debate and resultant controversy surrounding GM crops have been configured in Brazil, India and Mexico. The choice of three 'rising power' global South case studies is deliberate. The majority of scholarship on GM crops has been focused on global North settings with to date relatively minor engagement with the dynamics of the issue in the global South. Yet it will be in countries such as Brazil, Mexico and India – and in the global South more broadly – where agricultural innovation is most needed, where the bulk of food provision is expected to come from and where debates over GM technologies are likely to be most intense. We now set out a brief context on the development of GM crop technology and its take-up in developed and developing world contexts.[1]

A brief context

Since the second world war, crop yields have increased dramatically through three routes: improved hybrid varieties as a result of intensive selection breeding; the use of more effective agrochemicals (herbicides to prevent weed competition, pesticides to reduce damage by insect pests and fungal, bacterial, viral and nematode worm pathogens; and fertilisers to enhance soil nutritional quality); and altered agronomic practice (crop rotation, use of mechanisation and the introduction of larger scale farming). The development of hybrid high yielding varieties of cereal grains was a central plank of the Green Revolution. Hybrid varieties of especially rice, wheat and maize were researched and developed by mainly public agricultural research centres, such as the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico, the International Rice Research Initiative (IRRI) in the Philippines, and the Consultative Group on International Agricultural Research (CGIAR) with research centres across the global South. The widespread adoption of hybrid crops lead to steady increases in cereal production from the 1960s, and to the general transformation of agriculture, particularly in Asia and Latin America. Even though the successes of the Green Revolution have been challenged by critics – for leading to excessive use of fertilisers and pesticides, for benefitting large farms rather than smallholders, for leading to unnecessary mechanisation and to species-poor monoculture farming – such developments undoubtedly increased yields, helped feed a growing global population and arguably assisted in avoiding widespread famine in places such as India. However, in the last 20 years or so, this increase in crop productivity has levelled off, as progress in these three strategies for increased crop performance reach limits. This is becoming a problem for the near future, as the human population increases to a predicted 9 to 10 billion by 2050 from its current level of 7.2 billion. Populations in developing countries are increasingly demanding more meat in their diet, which requires more arable land and feed to generate it; while arable land availability is set to decline through adverse effects of climate change, soil salinisation and urbanisation of rural areas. Therefore enhanced crop yield is a key target for crops grown in increasingly difficult arable conditions.

Genetically modified (GM) crops are plants whose genetic material has been modified using genetic engineering techniques to introduce new and targeted traits. Genetic modification techniques offer the potential to 'speed up' traditional plant breeding by introducing selected novel genes into a crop plant in the laboratory, either from the same species (a process called cisgenics) or from another species (a process called transgenics). The technique developed rapidly during the 1980s and 1990s, generating novel transgenic plants that were then tested in field trials prior to approval and commercialisation. The use of GM technology is seen as being potentially valuable, as it allows the transfer of genes underpinning yield from wild relatives of crops that are not sexually compatible, and so not accessible to the conventional breeding programmes. By identifying specific genes in these relatives they can be cloned and transferred directly into elite varieties, for testing effects on yield. The two most common key GM traits that are commercially available are the use of *Bt* toxins for protection against particular insect pests (in non-GM crop protection strategies *Bt* toxins are sprayed onto fields to kill insects); and the use of herbicide tolerant genes, to protect crops against herbicides that kill weeds (herbicide tolerant crops may also be produced by non-GM mutational techniques, but this is difficult as it is non-targeted). Other traits are in development, including those that affect crop quality as well as yield, such as modified potato starch composition for industrial purposes, or modified lignocellulose for more efficient biofuel production.

In the US, the first GM crop approved for human consumption was the FlavrSavr tomato produced by Calgene in 1994, with an antisense gene added to slow the ripening process and delay rotting. Since 1996 the growth of cultivation of GM crops has increased dramatically. Of 1.5 billion hectares of arable land worldwide, approximately 175 million hectares or around 12 per cent are cultivated with GM crops. Of the 27 countries that planted GM crops in 2013, most were grown in five countries: the United States, Brazil, Argentina, Canada and India. The pattern of adoption is also shifting: since 2011 the developing world overtook the developed world in the area of GM crops under cultivation. Growth of the early adopters (US, Argentina and Canada) has slowed in recent years, reflecting near saturation in popular GM crops, while late adopters (Brazil and India) continue to expand cultivation. GM soya bean, maize (corn), cotton and canola account for nearly all GM crops. These figures are respectively 81 per cent of the global crop yield for soya, 35 per cent for maize, 81 per cent for cotton and 30 per cent for canola. These figures are produced in annual reports by the International Service for the Acquisition of Agri-biotech Applications (ISAAA), a pro-industry organisation whose mission is both to monitor and to promote agricultural biotechnology, particularly in global South contexts (see James 2013; for a critique of the ways in which ISAAA uses these figures, see Dominic Glover's commentary in Chapter 8, this volume).

The regulatory process governing the release of GM crops in Europe is focused on assessing the risk of a given GMO on human health and the environment (Conner *et al.* 2003). Each member state has a regulatory body (ACRE in the UK), which provides advice to government ministers. In the UK, ACRE is populated by members from a range of backgrounds, and includes ecologists, molecular biologists, biomedical scientists and farmers. They assess submissions for GMO release, whether it be for pre-competitive research projects or for commercial purposes. This advice is then published on the ACRE website, allowing public scrutiny. Decisions whether to market GM crops are made at EU level, by the European Food Standards Agency (EFSA) and its GMO Panel. Each member state has a veto on the decision for cultivation of the GMO in its territory (national safeguard measures), in which occasion the case goes to the Council of Ministers in Brussels for a final decision, taking account of the new evidence provided by the dissenting member state.[2] This process for commercial products is expensive and can take several years, and so is only possible for large companies with large budgets.

In the US, no single statute and no single federal agency govern the regulation of agricultural biotechnology products. Typically regulation of GM plants is under the control of the US Department of Agriculture (USDA) and the Environmental Protection Agency (EPA), while GM crop-derived food products are regulated by the Food and Drug Administration (FDA). Current US federal policy under the FDA takes the view that agricultural products derived from GM crops can safely be regulated under existing regulatory routes used for food products generated by conventional (non-GM) methods. This approach is based on the view that the safety assessment of food products is based on the properties of the product, rather than the manner in which it was produced. The assumption is that GM technology is not inherently riskier than conventional production techniques, and so it is the properties of the GM technology product itself, rather than the production process, which is subject to regulation. However, the US still requires a definition of 'genetic engineering' as part of the regulatory process, and so the system can be considered not to be purely product-based. Any GM food product is treated as a food additive and appropriate toxicology testing is carried out before use. This is nevertheless a key distinction between US and European policy, as in Europe the focus of regulation is the process of production rather than the nature of the product. Nevertheless, EPA and USDA still require approval for licences to carry out field trials, based on risk assessment.

Brazil uses a regulatory system that is very similar to the EU system, which operates under a general law on biosafety. Applications are assessed by the CTNBio, the Brazilian National Biosafety Technical Committee, and then have to be approved by Brazil's Agriculture Ministry and the National Biosafety Council (CNBS) before they can be planted. Canada does use a purely product-based, rather than a process-based, regulatory system, based on the notion of substantial equivalence, and is the only country to do this. In China, applications to release GM crops are submitted to the Office of Agricultural Genetic Engineering Biosafety Administration (OAGEBA), and assessed by the National Biosafety Committee. In Mexico, regulations take place within a general law on biosafety, where applications are assessed by three different agencies: the Agriculture Ministry (SAGARPA), the Environment Ministry (SEMARNAT) and the Health Ministry (SALUD), while the Inter-Ministerial Commission on Biosecurity and Genetically Modified Organisms (CIBIOGEN) coordinates biotechnology activities. In India, the Genetic Engineering Approval Committee (GEAC), part of the Ministry of Environment and Forests, is the body that approves applications for the commercial production of GM crops, large-scale field trials of GM crops, and the imports of GM commercial products. Approval for cultivation requires two-year field trails as part of the risk assessment process (See Nap *et al*. 2003 for an overview of regulations internationally).

Science and publics

Traditionally, it has been assumed that public acceptance of emerging technology is best assured through programmes of public education. According to this approach – which has been dubbed the deficit model of science communication – it is thought that public unease is caused primarily by a lack of sufficient knowledge (a deficit of understanding) and that the best way to overcome this knowledge deficit is through the provision of accurate and reliable information, which will not only improve scientific literacy but which will also engender public support and the acceptance of new technologies. This model was famously promoted in the UK in the Royal Society's *The Public Understanding of Science* report (Bodmer 1985). The report argued that public understanding of science was essential for the UK to make the most of its scientific potential. It adopted an 'information deficit' model that presumed that scientists are knowledgeable experts, that economic prosperity requires scientific expertise, that members of the public need to make decisions that involve science and technology in their everyday lives, that the public are in need of education in scientific literacy, and that scientists develop an explicitly public role to help the public understand science and their work (Wynne 1991).

Notwithstanding the considerable benefits that emerged from the subsequent growth of science communication as a mainstream practice, this model soon became widely discredited by scholarship in the science and technology studies (STS) community, not least for misrepresenting the diverse reasons that structure public concerns to potentially controversial science and technology. Indeed, a wealth of studies has demonstrated that people use different kinds of information to form judgements about a particular technology. For example, economic factors, culture, social values, political outlooks, trust in scientists, senses of agency, and worldviews have all been shown to be important in influencing public's attitudes to science (see Sturgis and Allum 2004 for a review of the literature). Other studies have developed a more radical critique, arguing that information about science cannot be separated from the institutional context in which it is produced, and thus that public perceptions of scientific information will depend, in part, on their experience of that institution's past behaviour (Wynne 1995; see also Grove-White *et al.* 2000).

In addition, the information deficit model was seen as failing to provide robust advice to assist policy-makers to deal with science-based controversies or to help governments to anticipate adverse public reaction to technological risk issues. The case of mad cow disease was especially traumatic for the UK polity where the failure to acknowledge the uncertainties surrounding the link between bovine spongiform encephalopathy (BSE) and Creutzfeldt–Jakob disease (CJD) led ministers to be ill-equipped to deal with the crisis, with considerable political fallout. The handling of the controversy over agricultural GM technologies in the UK was no less traumatic. Attempts by ministers to reassure the public that GM foods did not present new risks, or more precisely that there was 'no evidence of risk', and thus that public concerns were unreasonable, did little to allay fears or ameliorate the situation. In response, a number of influential policy reports were written, all calling for, inter alia, more proactive public involvement and deliberation in debates about the social and ethical dimensions of science and technology (see Department of Trade and Industry 2000; HM Treasury *et al.* 2004; House of Lords 2000; Royal Commission on Environmental Pollution 1998). The House of Lords Science and Technology Select Committee's *Science and Society* report, in particular, marked an important point of transition, where gradually the science communication movement, and then, more slowly, scientists themselves, realised that good communication must be two-way (House of Lords 2000). The report observed that the public's confidence in science had been rocked by science-based controversies around GM crops, BSE and nuclear power, and that science communication needed to be reconfigured to be fit for purpose. It said that science communication was too top-down and that scientists needed to learn to listen to the public better. In particular, it argued that dialogue with the public needed to become embedded in policy-making and in science itself.

Traditional approaches to governance have tended to presume that a technology should be permitted onto the marketplace in the absence of evidence of harm (to human health and the environment) and so long as it does not violate basic ethical principles (such as privacy, liberty, freedom of expression and autonomy). Such an approach is commonly enshrined in law. For example, in relation to GMOs, regulation and governance frameworks have been dominated by risk-based assessment methodologies. As set out above, different approaches to regulation have emerged between the United States and the UK/Europe, between broadly product-based approaches which assume that genetic engineering as a process presents no special risks that could not be addressed by existing product-oriented legislation, and process-based regulation which assume that the potential risks of GM crops require additional forms of control and regulation that cannot be accommodated with existing regulatory structures. Nevertheless, the assumption remains, that the key criterion mediating the release of GMOs into the environment should be an independent case-by-case risk assessment of its impacts on human health and the environment. For this reason, it is perhaps not surprising that the public debate surrounding GM crops has too often been boiled down to one of biosafety: are GM crops safe? Are they safe to eat? Are they safe to the environment? Are risk assessment methodologies sufficiently robust to answer these questions? What does the application of the precautionary principle mean in relation to these questions? And is it being applied appropriately?

This framing of the governance issue is commonplace. If the defining issue structuring the regulation of GM foods is an assessment of safety, if it is at bottom a question of sound and systematic scientific knowledge or innovation, and if there is as yet little definitive evidence of harms directly associated with GMOs, then it is difficult to continue to justify current restrictive regulatory practices on GM crops and foods, particularly in Europe and in other jurisdictions in the global South (including, as we shall see later in the book, in relation to certain crops in India and Mexico) where a precautionary approach has prevailed. For example, at the time of writing (August 2014), there exist a number of initiatives across the UK and Europe to relax regulation on GM crops to ostensibly make it 'fit-for-purpose'. For example, in relation to European regulation, an array of expert scientific advisory committees have argued that from a scientific perspective, there is no compelling evidence of GM crops posing any greater risk to humans or the environment than that associated with conventional crops, that the regulation of GM crops should therefore be no more stringent than their non-GM equivalents, that regulation should be reframed to focus on products (i.e. on whether a GM crop has novel trait characteristics) rather than on technology (i.e. on how it is made), that GM technology offers a range of potential benefits that may be being held back by misuse of the precautionary principle, and that regulation should be based on a risk-benefit analysis that than just an assessment of risks alone (see Advisory Committee on Releases to the Environment 2013a, 2013b, 2013c; Baulcombe *et al.* 2013; European Academies Science Advisory Council 2013).

There is a powerful logic to these initiatives. Relaxing current regulatory regimes on GM crops offer new potential for European nations to enhance agricultural productivity and yields, to improve agricultural productivity relative to major competitors, to respond to global food security challenges, to help farmers with disease control, to enhance the nutritional value of foods and to provide a production base for renewable industrial compounds and pharmaceutical products. However, there are dangers too. Perhaps most importantly, such a framing fails to engage with the reasons why GM crops have been rejected by European polities and publics, and why their uptake has been so uneven throughout the global South. Indeed, as we analyse in later chapters, we will find that institutional approaches to the governance of GM crops in Brazil, India and Mexico, have tended to be premised on a technocratic model, with few spaces for citizen engagement. We will find that there exists little institutional capacity (and appetite) to deliberate on the social and ethical dimensions of GM crops or to discuss their impacts at the level of culture and livelihoods. We will find that when science communication is undertaken (which is rare) it has tended to be conducted in a top-down manner, such that scientists and regulators rarely listen to the public and thus imperfectly understand the nature and intensity of public and stakeholder concerns, including those of smallholder farmers. And we will find that such dynamics have contributed to the decline of authority of decision-making on GM crops, which all too often have been rejected as biased, unlawful, unconstitutional and lacking in transparency.

Understanding the GM controversy

There now exists a body of social science scholarship on the GM crop and food controversy, using a range of intellectual resources and traditions. These include: actor network theory, bioethics, Christian ethics, cultural theory, democratisation theory, deliberative or participatory democracy theory, discourse analysis, globalisation theory, media analysis, mobilisation theory, political culture, public engagement studies, regulatory science, resource mobilisation theory, political economy, reflexive modernisation, science and technology studies, social amplification of risk theory, social representations theory and the sociology of expectations, among others. This considerable literature on agricultural biotechnology and GM crops includes detailed analyses of the controversy and its unfolding, from the perspectives of particular nation states as well as from a comparative perspective (for examples of the range of literature, see Bauer 2006; Bauer and Gaskill 2002; Fitting 2006; Frewer *et al.* 2004; Gaskell *et al.* 2004; INRA 1993, 2000; Jasanoff 2000, 2005; Levidow 1998; Levidow and Carr 2000; Marris *et al.* 2001, 2005; Newell 2008; Paarlberg 2001; Scoones 2008).

From the extant literature one can highlight four dynamics that help explain how the controversy emerged and the forms that it took in the UK, in Europe and across the global South. First, there is the argument that the revolutionary promises that were claimed for the technology by its early promoters – that GM technology would help the poor, alleviate poverty and hunger, address nutritional deficiencies, help feed the world, contribute towards sustainability and provide better quality foods – while perhaps plausible from a technological perspective, and while constitutive of a pervasive technoscientific imaginary (Marcus 1995), were not reflected in practice, at least as regards the outcomes of the first generation of GM crops (Conway 1999; Lipton 2001). The two main types of GM crops that currently exist – crops that have been rendered herbicide tolerant (HT) through the insertion of novel genes that code for resistance to the toxic effects of a herbicide (most often Roundup or Liberty herbicides), and crops that have been rendered insect resistant (IR) through the insertion of novel genes that code for insect resistance (usually from the soil bacterium *Bacillus thuringiensis*, commonly abbreviated as *Bt*) – were not designed explicitly with the aim of producing environmental or health or consumer benefits (see Economic and Social Research Council 1999). Both technologies were aimed to help the large producer, not the consumer or the environment, and can be considered to be mechanisation technologies, enabling farmers to reduce labour costs and to farm larger acreages of crops, such as soya and maize (Buttel 2005). These technologies were aimed at improving efficiencies in food production, not at affecting the quality of the food produced or of developing crops that respond to grand societal challenges.

The second observation concerns the very restricted scope for public and stakeholder involvement that exists in current processes of regulation and oversight of GM crop technologies, and in the lack of formal consideration of non-scientific social and cultural criteria in evaluation processes. Wider appreciation of, or sensitivity towards, public values or cultural considerations have not typically been regarded as relevant variables; indeed, opposition to GM crops has tended to be seen as based on ignorance, or as prejudice or at best as based on imperfect knowledge. Technologies have been promoted on economic grounds, with the market as the arbiter, while regulation was viewed as a technical consideration, conducted by case-by-case scientific risk assessment addressing specific harms to health and the environment (Grove-White *et al.* 1997). Thus, from the onset, questions concerning the ecological, social and ethical impacts of the technology – including how they would be distributed and how they might impact on public values and smallholder livelihoods – were excluded as bona fide questions within a risk-based approach (Jasanoff 2000). Assessments were conducted using tightly focused, product-specific methodologies, focusing on possible impacts (to human health and the environment) rather than on the complex economic, social and environmental contexts in which GM would be commercialised. Furthermore, this discursive construction implicitly served as the institutional representation of public concerns themselves, which regulation was taken to be addressing (Kearnes *et al.* 2006). In addition, major multilateral organisations such as the UN Food and Agriculture Organization (FAO) have increasingly restricted their contribution to that of brokering projects between donor and receiving countries, in tension with its normative mandated role, and their initiatives to broaden the conversation on agricultural biotechnologies have largely as a result remained inconsequential in terms of policy-making at local and national levels (Müller 2011).

In the global South in particular, the uptake of GM crops is associated with the widespread adoption of neoliberal policies aimed at the institutional reform of agriculture. Keenly advanced by international organisations – including the World Bank, the World Trade Organization (WTO), the International Monetary Fund (IMF) and the World Intellectual Property Organization (WIPO) – a global legal and regulatory regime has been developed based on ideals of market liberalisation, free trade, intellectual property rights and harmonised approaches to risk assessment (Busch 2010). Such a regime is enthusiastically endorsed and encouraged by the global seed companies, especially Monsanto, who due to the expansion of intellectual property rights and trade in agricultural products now controls an increasing share in the world seed market (currently about 23 per cent). Importantly, the seed companies themselves have promoted a restrictive approach to the regulation of GM crops across multiple jurisdictions, often invoking international trade rules, where social need is equated to that of the free choice of consumers in the marketplace, and where the scope of regulation is restricted to cover solely the scientific evidence of harms rather than the appraisal of social and cultural criteria (Newell and Glover 2003). Restricting public regulation and deliberation to a science-based analysis of harms, where wider issues and their associated framings and voices are effectively hidden from public accountability and influence, thus employs science 'to generate standardised procedures and processes which serve a particular model of global capitalism and … interests' (Scoones 2002: 14; see also Wynne 2001).

The third observation concerns the evolution of different approaches to regulation. As noted above, in the United States a regulatory regime emerged that considered genetic engineering as a process that presented no special risks that could not be addressed by existing product-oriented legislation (National Research Council 1989). This led to the principle of 'substantial equivalence' that came to govern international trade policy, including that of the WTO (Murphy and Levidow 2006). In Britain a more expansive view of the potential for GM technologies to generate harm developed, including those surrounding the industrial production of GMOs and their deliberative release. These were seen to require control and regulation that could not be accommodated with existing regulatory structures. Following a timely report from the Royal Commission on Environmental Pollution in 1989, in which emphasis was drawn to how much was still unknown about the impacts of GM technologies, a specific regulatory committee was set up in 1990, the Advisory Committee on Releases to the Environment (ACRE). Thus, a regulatory system developed in which the process of genetic modification became an appropriate basis for determining policy (Jasanoff 1995). This was complemented at the European level, starting in 1990, where GMOs were regulated under the Deliberate Release Directive 90/220, requiring member states to ensure that GMOs would not cause 'adverse effects' (Wynne 2001). In Mexico, India and Brazil, regulation followed a blend of European and North American models. In addition, regulatory regimes were driven in part by the need to implement the Cartagena Protocol on Biosafety, an international agreement that sought to protect biological diversity from the potential risks posed by GMOs, based on the precautionary principle.

The fourth observation is that these regulatory frameworks provided an 'opportunity structure' for NGOs – and later other actors including the media – to help define the issue as a public issue. While arguing within the parameters of risk and precaution to governments and regulatory bodies (this was the only tractable discourse available), they mobilised public support through a range of broader arguments: that GM foods would lead to an inevitable loss of consumer choice, that decisions had already been taken outside the public sphere, that GM crops would lead to the corporate control of food systems, that GM crops and foods would benefit only multinationals and large-scale farmers, that the technology was 'unnatural' and that there would be probable unpredicted effects beyond the reach of risk science. Importantly, these arguments, which were identified as 'latent' and cross-cutting public concerns even before the controversy took hold (Grove-White *et al.* 1997), were simply not captured by the formal and technical language of safety and risk. One effect of this deletion was to make debates over the risk and safety of GM crops stand-in for a host of other unacknowledged concerns (Frewer *et al.* 2004; Gaskell *et al.* 2004). Yet the intensity of these wider concerns was reinforced by the lack of any official assurances of the adequacy of current regulatory assessment mechanisms (Kearnes *et al.* 2006). In Mexico, India and Brazil, the Cartagena Protocol offered a space for differing interpretations as to how biosafety should be framed: should it be restricted only to risks to biodiversity alone or should it be expanded to include risks to human health or to wider socio-economic impacts?

The purpose of this section is to demonstrate that there exist diverse academic literatures that account for the controversy and the forms that it took in Europe and the global South, and that these highlight an array of (good) reasons why agricultural GM technologies have proved to be socially and politically controversial. Importantly, these reasons transcend the question of risk – whether the proposed technology will produce harm either to human health or the environment as identifiable through techniques of scientific risk assessment – and thus to dynamics where the provision of robust and reliable scientific information on harms will do little to provide socially robust governance. However, there is a wider point; namely, that if policy initiatives aimed at reconfiguring current regulation of GM crops are to ignore these social, cultural and institutional dynamics – which would appear to be the case in the governance initiatives outlined above which presume that regulation should proceed on a simple risk-benefit calculus – then it is entirely plausible that further attempts aimed at promoting the technology will lead to equivalent polemic and controversy, given that they offer little scope to engage with the issue within the terms of the debate as it is considered by an inclusive array of actors, including publics and farmers.

Yet how should governance engage with the issue within the terms of the debate as it is considered by an inclusive array of actors, including its 'non-risk' dimensions? This is a challenging question. If governance processes, often premised on formal risk assessment, have done little to identify in advance many of the most profound impacts that we have experienced through innovation, including those associated with GM crops and foods, how can we devise alternatives? Callon *et al.* (2009) use the metaphor of science and technology 'overflowing' the boundaries of existing scientific regulatory institutional frameworks. They point to the need for new 'hybrid forums' that will help our democracies to be 'enriched, expanded, extended and … more able to absorb the debates and controversies surrounding science and technology' (*ibid.*: 9). Yet, despite initiatives aimed at enlarging participation, current forms of regulatory governance offer little scope for reflection on the purposes of science or innovation or on their wider social and ethical downstream impacts. In this regard, emerging technologies typically fall into what Hajer (2003) calls an 'institutional void'. There are few agreed structures or rules as to how we should govern them in their 'beyond risk' dimensions. They are therefore emblematic of the move from old models of governance to more decentralised and open-ended governance, which takes place in new places – such as markets, networks and partnerships alongside conventional policy and politics (Hajer and Wagenaar 2003). We now offer three broad frameworks that offer novel ways to move beyond the institutional void in the governance of agricultural biotechnology.

A framework of responsible innovation

Responsible innovation has emerged in recent years, especially in Europe, as a science policy framework that seeks to align technological innovation with broader social values. Rene von Schomberg, who works at the European Commission, defines it as:

> A transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).
>
> *(von Schomberg 2013: 63)*

Responsible innovation seeks to reconfigure traditional approaches to technological governance by moving the site of governance away from the governance of risk to the governance of innovation, and by propagating a collective ethics of care and stewardship among scientists and innovators. Rather than relying simply on consumer choice and market mechanisms to determine what constitutes the benefits of a particular technology, and thus the directions towards which technology should be oriented, a responsible innovation approach suggests that these should be underpinned by shared public values.

There are different approaches to the identification of public values and thus the questions towards which science should be directed. One approach is to locate the 'right impacts' of science and technology in democratically agreed processes and commitments (in von Schomberg's case these are the values that drive European

Union policy). An alternative response has been to develop a typology of the kinds of questions public groups typically ask of science, and which they would like scientists and innovators to ask of themselves. In a recent study one of the authors developed a typology of lines of questioning derived from an analysis of cross-cutting public concerns across 17 UK public dialogues on science and technology (Macnaghten and Chilvers 2014). There were concerns with the purpose of emerging technology, with the trustworthiness of those involved, with whether people feel a sense of inclusion and agency, with the speed and direction of innovation, and with equity, whether it would produce fair distribution of social benefit. From this typology a framework of responsible innovation was developed for the UK research councils as comprising four interconnected dimensions[3] (Owen *et al.* 2013; Stilgoe *et al.* 2013). It was suggested that to innovate responsibly entails a collective and continuous commitment to be anticipatory, inclusive, reflexive and responsive (the AIRR framework) in relation to these kinds of questions.

The call for improved anticipation in governance comes from a variety of sources, from concerns with the pace of social and technical change, to critiques of the limitations of top-down risk-based models of governance and their inability to capture the social, ethical and political stakes associated with technoscientific advances (see Felt *et al.* 2007). The detrimental implications of new technologies are often unforeseen, and risk-based estimates of harm have commonly failed to provide early warnings of future effects (European Environment Agency 2002, 2013). Anticipation prompts researchers and organisations to ask 'what if …?' questions (Ravetz 1997), to consider what is known, what is likely, what is plausible and what is possible. Anticipation is distinguished from prediction in its explicit recognition of the complexities and uncertainties of science and society's co-evolution. Methods of foresight, technology assessment, horizon scanning, scenario planning and vision assessment can be important techniques to aid anticipation. Anticipatory processes need to be well timed so that they are early enough to be constructive but late enough to be meaningful (Rogers-Hayden and Pidgeon 2007).

As the authority of expert, top-down policy-making has declined in recent decades, policy-makers have sought the inclusion of new voices in the governance of science and innovation as part of a search for legitimacy (Irwin 2006). Over the last two decades, particularly in northern Europe and in some of the democracies of the global South, new deliberative forums on issues involving science and innovation have been established, moving beyond engagement with stakeholders to include members of the wider public (see Wilsdon and Willis 2004; Leach *et al.* 2010a). Small-group processes of public dialogue have been developed that now include consensus conferences, citizens' juries, deliberative mapping, deliberative polling, deliberative workshops and focus groups (see Chilvers 2010; Bächtiger *et al.* 2010). Andy Stirling has emphasised the importance of public dialogue in the 'opening up' of framings of issues that challenge entrenched assumptions and commitments (Stirling 2008; see also Lövbrand *et al.* 2011). And while there has been a resistance to attempts to proceduralise public dialogue for fear that it becomes another means of closure (Wynne 2005, 2007) or technocracy (Lezaun and Soneryd 2007), there have been efforts to develop criteria aimed at assessing the quality of dialogue as a learning exercise. On the latter, Callon *et al.* (2009: 160) offer three criteria: intensity – how early members of the public are consulted and how much care is given to the composition of the discussion group; openness – how diverse the group is and who is represented; and quality – the gravity and continuity of the discussion. Some authors have in addition stressed the need for normative standards of deliberation, that promote flexible forms of discourse and social interaction, that pays attention to pluralism and difference, and that embraces the potential for dialogue to generate heated disagreement and argument (Bächtiger *et al.* 2010; Avritzer 2012).

Responsible innovation demands reflexivity on the part of scientists and institutions. Reflexivity, at the level of institutional practice, means holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge, and being mindful that a particular framing of an issue may not be universally held. Unlike the private, professional self-critique that scientists are used to, responsible innovation makes reflexivity a public matter (Wynne 2011). Recent attempts to build reflexivity have tended to focus at the laboratory level, often with the participation of social scientists or philosophers. The argument is that in the bottom-up, self-governing world of science, laboratory reflexivity becomes a vital lever for opening up alternatives through enhancing the 'reflections of natural scientists on the socio-ethical context of their work' (Schuurbiers 2011: 769). However, reflexivity needs to extend beyond the contained space of the laboratory to embrace 'the wider range of activities, actors, interests, and relationships which constitute science and its distributed networks of stakeholders and innovation funders, practitioners and affected publics' (Wynne 2011: 794). These institutions have a responsibility not only to reflect on their own value systems, but also to build the reflexive capacity within the practice of science and innovation. Finally, a reflexive scientific culture is one where, according to Bruno Latour, scientists do not abandon the fruits of their creations, but cultivate instead a sense of care (and love) for technology and its downstream effects (Latour 2008).

There exist a range of processes through which questions of responsible innovation can be asked. However, for responsible innovation to have purchase, it must also seek that policy-making and science policy institutions are *responsive* to such questions. Responsible innovation requires a capacity to change shape or direction in response to stakeholder and public values and changing circumstances. The limited capacity of public engagement initiatives to modulate innovation trajectories has been a significant criticism (Stirling 2008). Responsible innovation requires that we design systems of innovation that are capable of responding to new knowledge as this emerges and to emerging perspectives, views and norms. There are various mechanisms that might allow innovation to respond to improved anticipation, reflexivity and inclusion. In some cases, the application of the precautionary principle, a moratorium or a code of conduct may be appropriate. In other cases this may require explicit regulation, the development of standards, the application of stage-gates or other mechanisms of transparency. While in other cases still, this may require institutional redesign, such as a new government commission, a reconfiguration of regulatory norms and procedures, or a change in departmental duty and remit.

Pathways to sustainability

The pathways to sustainability approach has been pioneered by the UK STEPS (Social, Technological and Environmental Pathways to Sustainability) Centre, an initiative funded by the Economic and Social Research Council that brings together development studies and science and technology studies, and whose research and policy engagement activities focus on how novel development pathways can be built in today's complex, dynamic and globalising world. The research focus of the STEPS Centre is sustainability, broadly defined, with projects on agriculture and food, energy and climate change, health and disease, and water and sanitation (see STEPS Centre 2010; Leach *et al.* 2007). The pathways approach embraces similar dimensions and aspirations to the responsible innovation framework – for example, the need to analyse technological innovation through a social and institutional lens, the need to include local knowledge in technological decision-making, the need for reflexivity in innovation and governance practices, and the need to open up new governance pathways that are more responsive to local realities – but with important elements of difference and emphasis.

A key point of difference lies in how the pathways approach attempts to link technological innovation with questions of social justice and environmental integrity. Focusing on the needs of the poor is an explicit theme of the approach, both in terms of seeking greater recognition of the everyday realities of marginalised peoples and in terms of developing policies aimed at addressing their needs. This 'critical' stance informs both the object of study and the purpose of research and policy engagement. It also informs research methodologies that employ broad 'systems' framings to sustainability challenges. Borrowing from science and technology studies, the pathways approach emphasises the importance of framing. Different ways of framing an issue or a problem by different kinds of actors will lead to different ways of understanding and representing the system and thus to different pathways for problem resolution (Leach *et al.* 2010a). Framing involves choice – about which elements of the system to include and exclude, about whose knowledge counts and whose does not, about what scale is appropriate, about what constitutes policy resolution – and the pathways approach attempts to open up new choices, particularly those oriented towards the needs of the poor, as well as making existing choices more accountable. Given this focus on multiplicity, the pathways approach seeks continuously to resist, contest and challenge dominant pathways – and their associated framings and narratives – and to open up alternative, hidden and otherwise marginalised pathways to sustainability.

A further and interconnected theme concerns how the pathways approach engages with the dynamics of complex social and ecological systems, such as climate change, mobility and globalisation, and the multiple ways in which these are structuring everyday realities. It is argued that traditional policy approaches to sustainability and development challenges have all too often promoted simple solutions to complex problems that have tended to emphasise stability and control, equilibrium and predictability, and controllable risks (Leach *et al.* 2010b). Commonly this has involved the promotion of top-down, high-tech, capital-intensive, singular, imported, path-dependent 'magic bullet' solutions to problems that are by nature complex, uncertain, dynamic and context-specific, and that it is this disconnect that arguably has generated resistance, contestation as well as frequent backlashes from nature. From sustainability issues ranging from global food security to urban over-crowding, from the problem of drought in dryland India to debates on seeds in Africa, from global health pandemics to the challenges of climate change, the pathways approach seeks to embrace the dynamic interactions between social, technological and environmental processes and the diverse ways in which different people and actors understand these across multiple scales and contexts. A key current critical preoccupation lies in contesting an increasingly prevalent global environmental policy rhetoric in which authoritarian forms of planetary control are seen as a necessary prerequisite to securing sustainable environments and where democratic processes are identified as a dispensable luxury. Again, a pathways approach points to the hope of integrating sustainability with social justice, or, in the words of co-director Andy Stirling, of seeking 'radical progressive social transformation [lying] more in the mutualities of caring, than in the hierarchies of control' (Stirling 2014: iii).

The pathways approach has fostered a broad repertoire of research methodologies: from qualitative in-depth methodologies that are able to listen attentively to the needs, concerns and 'problem framings' of poor and marginalised peoples; to more interactive and deliberative methods such as participative impact pathways analysis that engage actors, explore framings, address dynamics and co-construct new pathways (Douthwaite *et al.* 2009); to more formalised methodologies such as multi-criteria mapping that enable both the broadening of appraisal and its communication to wider political actors (Stirling 2007, 2010). Similar to the responsible innovation framework the overarching aim is to make technological governance more responsive and where a broader array of options, values and imaginations can be taken into account.

Culture and forms of life

The final element of our analytical framework concerns the relationship between technology, culture and forms of life. In a classic publication, Langdon Winner argued for the need to appraise technologies beyond the language of impacts and side effects, arguing that it is a mistake to present technological change as a 'cause' that produces 'effects' or 'impacts' (Winner 1986). Using Wittgenstein's concept, Winner argues that technological innovations are better regarded as 'forms of life' in that they embody distinctive social, political and ethical values and histories. Technologies, according to this approach, are not merely instruments, but are also connected to social practices that (potentially) have the power to transform life, social relationships and social structures at the level of ontology and meaning.

GM crop technologies can profitably be analysed from within the boundaries of this approach. GM crops are researched and developed in the laboratory, tested in the field and then transported for commercial cultivation across the globe, increasingly to locations in the global South. Conventional regulation and associated forms of risk analysis take little or no account of the 'forms of life' of GM crop technologies given that these dimensions extend beyond a simple analysis of harms. However, we cannot assume that GM crop technologies will be adopted and legitimated merely through appealing to scientific authority. Or, as Sheila Jasanoff puts it, GM crops cannot be assumed to 'travel friction-free across political and cultural boundaries' (Jasonoff 2006: 288). Expanding on this point, it is necessary to understand how GM crops are envisioned within the culture of the laboratory and what happens to these guiding visions when they travel from the laboratory to the field. What assumptions are being written into the design of the technology system? And how realistic are they in the context of use? To answer this latter question requires analysis on how GM crops are impacting on the livelihoods, cultural practices and forms of life in agricultural communities. Such analysis requires methodologies that rely on 'thick description' (Geertz 1973), searching for meaning through ethnographic engagement with everyday practices and through structured interaction.

To understand the ways in which GM crops and intersecting with local cultural practices necessitates a particular understanding of culture. Our approach is one that does not view culture in the classic sense of a 'bounded, autonomous entity with an internally coherent system, pattern or logic' (Fitting 2006: 25). We do not equate a 'society' or 'social group' with a fixed, static and prescriptive 'culture' or 'cultural form'. Our approach rather is one that views rural communities as constituting cultural worlds which are dynamic and unfolding, that emerge within geopolitically and historically informed contexts, that interact with, adopt and at times resist aspects of science-based agriculture, and that (re)constitute local practices and meanings in interaction with broader social and political dynamics, including those of globalisation, neoliberalism and rural reform (see Escobar 1995; Richards 1985). We view GM agriculture as a setting where technical decisions and cultural considerations are not external to one another, but mutually related. Nevertheless, agricultural innovations disseminate and impact on socio-cultural practices in often asymmetric and power-laden ways, differentially affecting people's forms of life. How GM crops are understood and adopted by smallholder farmers in specific geopolitical contexts are thus likely to be different from largeholder and industrial producers' understandings, be it in the same or different geographical locations, reflecting distinctive systems of production, historical trajectories and socio-cultural lifeworlds.

Being culture-sensitive also warrants a sensitivity to discourse and narrative. In particular, this requires an orientation to the rhetorical arguments of relevant actors who have a stake in GM crop technology: in its research and development, its adoption and implementation, and in its governance. Given the demands of social justice, particular attention needs to be drawn to the views and perspectives of actors who have been marginalised or excluded or whose views remain poorly articulated and understood: typically smallholder farmers, women and indigenous communities. Sensitivity needs to be given to the ontological, spiritual and religious dimensions of GM crop technologies and to their potential to disrupt moral boundaries and orders, such as people's everyday sense of nature, the sacred and the rightful place of technology both in crops and in foods (Deane-Drummond *et al*. 2003).

There are two additional considerations on the relevance of culture. The first has to do with the political claim to the recognition of groups who are mobilising around food and agricultural development and who are voicing their reasons in cultural terms (Mann 2014; Gledhill 2007). The second has to do with the need to include a plurality of actors and voices in the implementation of development projects, as a condition of justice and efficacy (Nazarea *et al*. 2013; Marshall 2008; Chaturvedi and Rao 2004). Development projects and policies acquire legitimacy in this context to the extent that they show awareness of cultural difference and give due consideration to the claims of culture (values, community life, worldviews, religious practices, etc.). In both cases, we are confronted with organised, collective action that are demanding that scientists, technicians and policy-makers listen and pay heed to how communities are affected by technological change (such as GM crop technologies) within their own terms of reference. Such cultural agency thus embodies a claim to participation and to the inclusion of different forms of knowledge (including, for instance, the social sciences and the humanities) within a conversation that has so far been restricted largely to economic agents, scientists and governmental actors.

Introducing the GMFuturos research

Our analytical approach was shaped by the conceptual debates outlined above. Central organising themes included the following:

- The need to engage with the dynamics through which GM crops are being promoted, implemented and at times resisted across different scales and contexts (responding to the dimension of dynamics).
- The need to explore how the issue of GM crops is being understood within the terms of the debate as perceived and understood by an inclusive array of actors, including publics, scientists and farmers (responding to the dimension of inclusion).
- The need to uncover narratives and discursive arguments about GM crops from within the perspectives and practices of actors who have tended to be marginalised in discussions on governance (responding to the dimension of

culture), including their reasons for rejection and contestation (responding to the dimension of social justice).

- The need to identify the competing ways in which different actors frame the issues surrounding GM crops and whether there exist disjunctions between official institutional and lay framings (responding to the dimension of framing).
- The need to identify how agricultural GM technologies are being understood and developed in national biotechnology laboratories and the extent to which, if at all, crops scientists are able and motivated to reflect on their own values, commitments and assumptions (responding to the dimension of reflexivity).
- The need to understand the questions GM crop technologies raise concerning the meaning and purpose of life, nature, knowledge, rights, responsibility, identity, democracy, the sacred, the future and the relationship between humans and the earth (responding to the dimension of ontology).
- The need to examine the capacity of existing forms of regulation and governance to respond to the issues surrounding GM crops, beyond the question of physical harms, and to experiment with more inclusive and democratic forms of governance (responding to the dimension of responsiveness).

The case studies chosen for empirical research were three global 'rising powers', namely Brazil, India and Mexico, each of which has enjoyed a particular and often turbulent historical relationship with GM crops. As will become evident in Chapter 2, the debate surrounding GM crops in Mexico has been dominated by social and cultural sensitivities surrounding maize. Mexico is the centre of origin of maize and traditional maize agriculture continues to be practiced by over 2 million farmers. Maize is and has been a fundamental part of the Mexican diet and of its culture and society, for millennia and up to the present day. This specificity provides thus a case study to examine how cultural arguments are accommodated (or not) within regulatory frameworks on GM crops hitherto dominated by risk science. It also represents an opportunity to examine how the voices of diverse stakeholders – notably smallholders, indigenous groups and religious organisations – are heard (or not) within a macro-economic context of increasingly neoliberal policy-making.

Brazil represents a different case. As we will see in Chapter 3, following an period of intense confrontation involving broad coalitions both for and against the technology, Brazil's approval and application of GM crops since 2005 has been rapid and to some sense remarkable. The Brazil case offers the opportunity to examine the factors that contributed to this rapid growth of application by farmers, while taking into account the manner in which various actors and coalitions have been resistant. It also offers an opportunity to examine the ways in which GM crop technologies have been adopted into local agricultural practices, with a particular focus on GM soya. Finally, it offers an opportunity to explore how lay people feel about eating GM foods (which they now have been doing for a decade, even if many are unaware of this) as well as their responses to the wider public debate.

India represents a different case once more, as evidenced in Chapter 4. With the exception of GM cotton, India established in 2013 a moratorium on GM crops, a response to the perceived limitations of its regulatory system as well as a reflection of widespread cultural sensitivities. India offers an opportunity to diagnose why the debate has not been settled (as might on the surface appear to be the case in Brazil), and to understand how key stakeholders, including scientists comprehend this uncertainty. Given the size of the country, India further offers the opportunity to understand how the public interest has been represented: whose voices have been seen to count and whose have not, as well as how scientists are framing the 'public value' of GM crop technologies and their relationship to Indian society. The strong ethnic and religious intimations of Indian rural communities (where a large majority of the population still live) also highlight the complexity of the debate, as regards scientific and policy forms of reasoning.

The choice of case study was thus determined in part by the very different experiences of GM crops in each of these national settings, situated within the indisputable policy imperative for the sustainable intensification of global agriculture. Nevertheless, even though strategically important to the future of world agriculture, and even though each country has its own uneven relationship with GM crops, little social science analysis on GM crops and their associated controversy has been undertaken in these global rising power settings compared to the considerable literatures that exist in the UK, Europe and North America (for notable exceptions, see Bauer 2006; Bowles 2003; Fitting 2006, 2011; Guivant 2002, 2006, 2009; Herring 2006; Leite 2000; Scoones 2006, 2008; Menasche 2003; Stone 2010; Toke 2004; Zanoni and Ferment 2011). Our research thus sought to add to existing scholarship in at least five ways: to examine how GM crops have been understood and embedded into everyday rural practices; to understand how crop scientists perceive GM crops and their relationship to society; to understand how lay people think about GM crops and foods and the factors that shape the formation of public attitudes; to compare responses to GM crops across three global South contexts; and to develop a new kind of deliberative space in which stakeholders can discuss the conditions, if any, under which GM crops can be developed cognisant of public values. In addition, by working with local partners, we sought to build local capacity.

The empirical research was undertaken in collaboration with local partners in Brazil (led by Dr Julia Guivant and her team at the Federal University of Santa Catarina) and Mexico (led by Dr Marta Astier and her team at the National Autonomous University of Mexico), and directly with a local researcher in India (Kamminthang Mantuong). A set of research activities was developed for each of the three case study sites (Brazil, India and Mexico). The in-country field research took place in each national setting over a nine-month period and was conducted by local researchers, overseen by Durham University. The research began with a focused literature review that guided and contextualised the research for each of the local case studies. This was followed by a training workshop, designed to harmonise research methodology and analysis across the three local research teams and to provide specific training in the distinct methodologies of the project (focus groups, ethnographic fieldwork, participant observation, in-depth interviews).

Ethnographic fieldwork was conducted in local rural settings over a nine week period with farming communities in three localities, and with each case study focusing on a different crop: in Brazil on soya, in Mexico on maize, and in India on cotton. The ethnography included a mix of participant observation and interviews with smallholder farmers, with local actors in charge of food preparation, with owners of small food businesses and with consumers. The ethnography provided data on socio-cultural practices and on the experiences of groups who tend to be unrepresented in debates on GM crops and foods. It enabled the mapping of pathways and sets of social relations surrounding the preparation and commercialisation of food (involving both GM and non-GM crops) as well as the identification of people's understanding of GM crops and their governance. A particular focus lay in observing and engaging in local agricultural and food practices including, where appropriate, food-related festivals and fairs.

The ethnography was complemented by interviews and questionnaires to understand stakeholder views on GM crops, debates and governance in each country. Structured interviews were conducted with a selection of stakeholders representing different categories of actor involved in the GM issue. These included: natural and social scientists, regulators, smallholder farmers, medium- and largeholder producers, indigenous groups, women's and religious associations, consumers' associations and seed companies' representatives. The structured interviews followed a standard schedule of questions. Questionnaires were administered via email to a selection of local and national stakeholders representing the same categories as above. The decision to undertake either structured interviews or questionnaires in each context was taken by local partners in response to local conditions and possibilities.

A two week participant observation ethnography was carried out in a public or non-profit agricultural research laboratory, selected in consultation with local teams, to provide data on the culture and dynamics of public research laboratories, to explore how laboratory scientists perceived GM crops, how they understood GM governance and regulation, how GM crop research was situated within the strategic mission of the laboratory, and how this was contextualised within wider debates on the future of agriculture and global food security. It further provided data on how laboratory scientists considered their social responsibility, how they conceived of their relationship with wider society and the extent to which they were able and motivated to reflect on their own commitments, values and assumptions. The research included between five and ten formal interviews with practicing laboratory scientists, and questions for informal interviews.

Four to five focus groups were undertaken in each of the case study settings with lay publics in mainly urban contexts, to develop in-depth understanding of how lay people think about GM crops and foods, in situations of unfamiliarity. The focus groups were recruited to reflect a spectrum of social classes and age groups, designed to cover a diversity of background but with topic-specific variants, including a particular bias towards women, the middle classes and religiosity. The materials were developed by the authors and presented using a data projector. The focus groups began with a discussion of food, of everyday food practices and of the appropriate role of technology in food. This was followed by a discussion on the concept of GM foods and crops: what they are, the history of their production and use, their diffusion into different kinds of food products, the existence of labelling schemes and the potential for GM crop technologies to create new kinds of foods in the future. Current societal and scientific debates on GMOs were then set out and discussed, including those which were in favour of the technology and its widespread application and those against. The participants then explored the responsibilities and roles of different actors in the debate, including their own. In each case the recruitment was topic blind. This design permitted analysis of how diverse contextual factors were embedded in everyday life practices and how these underpinned and framed the formation of subsequent attitudes and views on GM crops and foods.

Following the fieldwork, each local team organised a national deliberative workshop in collaboration with Durham University. Representatives of the eleven key categories of local stakeholders, including specifically excluded groups and voices, were invited to each of the workshops to discuss their positions with respect to GM crops and foods and to respond to a presentation of the case study results. These workshops were devised as a platform for the presentation and discussion of findings, a research arena to observe and analyse discourses and arguments, and a deliberative and experimental space to design, test and promote new forms of dialogue. The findings from each fieldwork case were written up in a national report setting out the social and cultural factors that shape local responses to GM crops.

Notes

1 We would like to acknowledge the contribution of Keith Lindsey in the writing of the following section.
2 See http://ec.europa.eu/food/food/biotechnology/qanda/d1_en.htm.
3 Since 2013 this framework on responsible innovation has been formally endorsed and taken up by the UK's largest public funding body, the Engineering and Physical Science Research Council (EPSRC); see www.epsrc.ac.uk/research/framework.

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2

AN ANALYSIS OF THE GM CROP DEBATE IN MEXICO

Susana Carro-Ripalda, Marta Astier and Patricia Artía

A review of the debate in Mexico

The present GM controversy in Mexico can only be fully understood if we cast a look back to the 1940s and 1950s, when the Green Revolution took place in the country. The Green Revolution had its origin in Mexico, supported by the Rockefeller Foundation and the federal government of Mexico, and its main aim was the development of high yield seeds for basic crops which were presented as critical in the battle to end world hunger (Massieu Trigo 2009). The International Centre for Improvement of Maize and Wheat (CIMMyT in its Spanish acronym) concentrated its efforts on the improvement of seeds for those two crops. However, it soon became evident that those new seeds required an associated high-cost technological package, including irrigation, machinery and agro-chemicals, which was rarely affordable for smallholder producers. Some Mexican scientists began to advocate the need to create more appropriate technologies for poor subsistence farmers, and many joined forces to fund the first school of ethnobotany in the country, at the Universidad Autonoma Chapingo, which has trained thousands of agro-ecologists ever since.

These facts are key to the understanding of two underlying conditions in the Mexican GM crop controversy. First of these is the still relevant polarisation between largeholder farmers, many of them in the northern states, who in general have benefitted from new agricultural technologies and resource capitalisation; and smallholder farmers, living mostly in the central and southern states, and who practice mainly subsistence, rain-fed agriculture (Massieu Trigo 2009; Hewitt de Alcántara 1985, 1999). This division is reflected in a de facto state of affairs in which development operates at two speeds in Mexican rural society. The other underlying condition in the Mexican GM controversy is the paradigmatic division between scientists who work on the development of advanced agricultural technologies, including biotechnologies, with the aim of increasing yield and production for market-oriented purposes; and those scientists who, even if they work in laboratories on molecular biology or genetic research, engage with smallholder farmers with the aim of promoting sustainable and appropriate rural technologies for the improvement of production at the local level.

Another fundamental aspect of the GM Mexican controversy is that, in essence, it focuses almost entirely on maize (corn), with other plants excluded from the main debate to a large extent. This rather unusual focus on one particular crop has multiple explanations. First, Mexico is the centre of origin and diversity of maize, and hosts around 60 landraces and thousands of native varieties, as well as wild varieties such as teosinte (thought to be the precursor of domesticated maize; see van Heerwaardena *et al.* 2011). Much native (or criollo) maize biodiversity is conserved *in situ* by smallholder traditional farmers (Soleri *et al.* 2006). Traditional maize agriculture (small-scale, rain-fed, mainly for subsistence) is practised by more than two million farmers, and dominates some regions, particularly those with large indigenous populations in the centre and south of the country. This type of agriculture is arguably vital for many rural areas, and still produces most of the white maize for direct human consumption in the country (Turrent Fernández *et al.* 2012). Second, and in addition to having been domesticated by early inhabitants in the River Balsas area over 9,000 years ago (Hastorf 2009), maize has always being a fundamental part of the Mexican diet, of its economy and politics, and of its society and culture. There is much evidence about the social and cultural significance of maize in Mesoamerican pre-Hispanic societies, and of its central place in their cosmology (Popol Vuh 1971). In present day Mexico, white maize is still consumed directly by most of the Mexican population from all social and geographical backgrounds, on a daily basis and in a variety of forms: 53 per cent of caloric intake and 39 per cent of protein intake is claimed to come from direct consumption of maize in Mexico (Toledo *et al.* 2013). Most importantly, maize holds a special place in Mexican people's hearts, and is linked by many to a Mexican sense of cultural identity (Fitting 2011; McAfee 2008; CEC 2004).

A brief history of the controversy on GM maize

Until the 1970s, agricultural policy in Mexico was governed by a dominant policy narrative of seeking self-sufficiency in basic food grains. Following the 1982 debt crisis, a new policy narrative was developed, centred on trade liberalisation, privatisation and the reduction of subsidies for smallholder agriculture. This narrative was further consolidated through Mexico's participation in the General Agreement on Tariffs and Trade (GATT) in 1986, in the North American Free Trade Agreement (NAFTA) signed in 1992, and in deliberations hosted by the Organisation for Economic Co-operation and Development (OECD) which Mexico joined in 1994. The development of GM crops took place within this macro-economic context, and the regulation of agricultural biotechnology became tied to broader policy discourses surrounding trade liberalisation and global integration. Thus, when an original moratorium on GM crops was withdrawn in 1988, private companies including Monsanto as well as public research institutions were able to develop field trails on GM canola, cotton and soya, with a particular focus on GM maize (CONACYT-CONABIO 1999), leading to subsequent significant increases in GM crop cultivation. Between 1988 and 2006, 373 release permits were issued (Bognar and Skogstad 2014), and by 2012, Mexico had 160,000 hectares under biotech crops, mainly insect resistant *Bt* cotton and herbicide tolerant GM soya (James 2012). In addition, GM maize began to be imported from the US in large quantities, initiating public controversy in Mexico.

The General Directorate of Plant Health (DGSV), at the Ministry of Agriculture, was in charge of granting permits for scientific field trials of GM crops, advised by ad hoc committees of scientists and government agencies. A stable advisory committee, the National Agricultural Biosafety Committee (CNBA), was established in 1992 (Fitting 2006: 18–19). The first law regulating GM crops, NOM-056-FITO-1995, was approved in 1995 (Bognar and Skogstad 2014). However, in 1998 the Directorate imposed a de facto moratorium on GM maize trials for two reasons: first, because of the argument that GM maize would be of limited economic benefit to Mexico; and second, because of growing concerns about the potential for GM maize to mix with native landraces and to displace criollos and teosinte (Fitting 2006: 19).

A year later in 1999, two events took place which had the effect both of amplifying and polarising the debate and of transferring it from the enclosed confines of the scientific and regulatory community to the public arena. First, Greenpeace (2000) discovered GM maize in a cargo of maize being shipped from US to Veracruz, as permitted within the frame of the NAFTA free trade treaty. They launched a vociferous anti-GM maize campaign with high profile partners from universities and international NGOs (Fitting 2006). In parallel, a group of concerned scientists sent a letter to the then president Ernesto Zedillo asking for more effective regulation of GM crops. He responded by creating the Inter-Ministerial Commission on Biosecurity and Genetically Modified Organisms (CIBIOGEM, which substituted the CNBA) in 2002. However, this body was surrounded by controversy from the beginning, as one of its original members, a former academic at the National Autonomous University of Mexico (UNAM), changed employment to AgroBio Mexico – an influential consortium of biotechnology companies that included Monsanto, Novartis, Dupont and Savia as partners – and started promoting GM actively (Massieu Trigo 2009). These national events took place alongside the signing of the Cartagena Protocol on Biosafety as an international backdrop. This protocol, although purportedly based on the precautionary principle, reflected nevertheless the pre-eminence of international trade treaties over its own jurisdiction.

Another turning point, which contributed to the increasing polarisation of the controversy, occurred when Berkeley scientists Ignacio Quist and David Chapela published an article in the journal *Nature* in 2001, stating that they had discovered the cauliflower mosaic virus, which is used in most transgenic crops, in native maize fields in Oaxaca. The article received much criticism from certain sectors of the scientific community, and the journal withdrew its support for it; CIBIOGEM however did not react (Massieu Trigo 2009). Later, studies in Oaxaca and Puebla funded by two government agencies, the National Institute of Ecology (INE) and the National Committee for the Study and Use of Biodiversity (CONABIO) corroborated Quist and Chapela's findings. At this point the controversy centred not only on the scientific reliability of evidence of transgenes in native maize, but also on whether transgene flow could signify a natural and desirable process, beneficial for the plant (a thesis supported by SAGARPA, the Ministry of Agriculture, among others) or, to the contrary, whether it constituted genetic contamination, and thus a threat to native maize biodiversity (Fitting 2011). By now the issue had jumped into the political arena, and the first debates about the necessity of a biosafety law took place at the Mexican congress.

In 2002, the first broad anti-GM maize coalition came into formation, comprising hundreds of activists, farmers, academics, indigenous groups and NGOs, who attended the forum *En Defensa del Maiz* in Mexico City. This forum was organised by the Centre for Studies for Change in the Mexican Countryside (CECCAM) and its participants aimed to shift the debate on GM crops away from technical considerations of gene flow to wider social issues. According to Fitting (2011), this was the point at which the emergent anti-GM coalition ceased to refer to 'risk' as exclusively 'genetic risk', and began to portray this notion within an expanded frame of meaning which encompassed political economy and socio-cultural readings. Thus the narrative of risk also came to be understood and represented in debates as the threat posed by GM crops to traditional smallholders and indigenous agriculture, and to the cultural diversity of rural society and ways of life. Criollo maize and its protection came to signify the defence of Mexican culture and identity in the face of unwanted and imposed global pressures. Also, in 2002, another campaign developed, *El Campo no Aguanta Más* ('The Countryside Cannot Take It Anymore'), set up by a coalition of 14 peasant groups. They organised an event attended by 100,000 demonstrators, protesting against NAFTA and neoliberal policy-making and demanding the halt of GM food imports (Fitting 2006: 24). Meanwhile, the Ministry of Agriculture (together with the biotechnology industry) continued to reject studies commissioned by NGOs which reported GM maize presence or contamination in the Mexican countryside. This suggests that the debate was contested at both a technical and at a social level, reflecting disputes over whose knowledge counts and on what authority.

At the time, the GM crop debate was gathering complexity, and divisions between groups and actors were neither obvious nor simple. For instance, the rift between scientists who advised the government on GM matters on the one hand, and technocrats and politicians who sought to accelerate GM crop implementation in Mexico on economic grounds on the other, was made explicit in 2003 when the Consultative Council of the recently created CIBIOGEM resigned in full, arguing that their recommendations had not been adequately taken into account by the executive. In 2004, and while debates on a future biosafety law were taking place in parliament, the CEC (Committee for Environmental Cooperation in North America, connected to NAFTA) issued a report about transgenic contamination in maize in Oaxaca (which had been commissioned by a coalition of NGOs and farmers) recommending the need for caution and for further research to be undertaken before the release of any GM maize in the country (CEC 2004). At this point, the Mexican Academy of Sciences proposed a bill for a biosafety law, which was later approved by the Mexican Senate. The bill was opposed by NGOs due to a perceived lack of transparency in the deliberation process, and matters were made worse when the Undersecretary for Agriculture signed an agreement with USA and Canada relating to permissible GM content in imported food crops, even though these did not conform to existing Mexican legislation (Massieu Trigo 2009). In the meantime, other studies appeared which corroborated Serratos's research (1998) regarding the lack of economic benefits of *Bt* GM maize due to prevalent Mexican agricultural conditions, as well as outstanding risks.

The Mexican Biosafety Law was finally approved in March 2005. Its approval was immediately followed by public protests, and the law was quickly nicknamed 'Monsanto Law'. In the same year the public forum *Sin Maíz no hay País* ('Without Maize, There Is No Country'), was organised at the National Museum of Popular Cultures with a wide and varied audience. The following year witnessed the creation of the Unión de Cientificos Comprometidos con la Sociedad ('Union of Socially Concerned Scientists'), a group headlined by respected and well-known scientists, 'who defended a critical position to withstand the pressure of multinationals who were promoting the introduction of commercial varieties of GM maize in Mexico' (Massieu Trigo 2009: 235; translation is the authors'). This group held a number of public forums on the issue of maize, which were well attended by scientists, intellectuals, NGOs and the general public.

The first round of applications for GM field trials under the new Biosafety Law were submitted in 2006, although they were immediately suspended because of questions about their legality. A coalition of academics, NGOs, smallholder farmers and indigenous organisations continued public activities against the impending implementation of GM maize in Mexico, and maintained a presence in the national press. The biotechnology companies also started a more active campaign of public engagement, more specifically around the issue of maize; for instance in 2007 Monsanto signed an agreement with the CNC, the National Peasant Confederation, in order to investigate the genetic diversity of this plant (Massieu Trigo 2009). However, the CNC is affiliated with the PRI (the party which held the presidency in Mexico from 1929 to 2000, and regained it in 2012 with Peña Nieto) and has been involved in a number of high profile corruption scandals, and thus its neutrality in the GM maize issue has been doubted by many.

Although the involvement of individual states and regions in the GM maize controversy in Mexico has been limited, in 2008 the PRD (the left-wing opposition party) government of Mexico City (a federal entity with a population of over 22 million people and with a peri-urban agricultural area), declared this city a GM-free area. Also the state governments of Michoacán (Congreso de

Michoacán de Ocampo 2011), Tlaxcala and some communities in the Sierra Tarahumara in the north have followed this path, although with varied results (Santillán 2013). The state parliament of Oaxaca declared its territory an 'in situ germplasm bank for maize' (Fitting 2011: 69). 2008 was also a crucial year as the special protection for maize when the NAFTA trade agreement came to an end, a fact which ignited a new wave of social protest in the country.

The controversy has remained active in the past few years, and many anti-GM stakeholders feel that, within the new contexts facilitated by the Biosafety Law, the developments in regulation aimed at facilitating the entry of GM maize in Mexico have accelerated and have run in parallel (although largely unrelated) to public debates. On the other hand, many scientists, regulators, politicians and the biotechnology companies, who defend the need and benefits of GM maize for the development of Mexican agriculture, feel that the issue is unnecessarily slow, and that there are too many impediments in the implementation of the law.

In 2009, the Regime for the Special Protection for Maize became active, and a dedicated public laboratory was created to detect, identify and quantify GM maize in the country. Yet in 2012 a new Agreement for the Centres of Origin and Genetic Biodiversity of Maize was approved, which annulled a previous agreement (which had seen the whole country as the centre of origin) and declared that large areas of the eight northern states could legitimately be planted with GM maize. It is interesting to note that the chosen states are those with an already established form of largeholder industrialised agriculture based on hybrid maize. In June 2012, SENASICA (Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria) authorised Monsanto to plant 253,500 hectares of GM soya in seven states of Mexico, 60,000 hectares within the Yucatán peninsula. This approval was contested by an amalgamation of associations of honey producers and NGOs, arguing that the resultant honey would violate the European Union's rule for GM-free honey. Legal permission was suspended although 10,000 hectares were eventually cultivated in 2012, mixed with non-transgenic soya and sorghum. Such a precautionary move was vindicated in research undertaken by Villanueva-Gutiérrez *et al.* (2014) that found evidence of GM soya pollen in Yucatan honey.

The GM maize controversy saw a resurgence at the public level in 2013, when the first permits for commercial cultivation in GM maize in the northern states of Sinaloa and Tamaulipas were about to be processed. There were complaints from many scientists, NGOs and other public organisations within the loose anti-GM maize coalition about the opacity of the application and complaint procedures, and about the lack of information on the outcomes. Within this climate, new civil society actors joined the anti-GM campaign, such as YoSoy123 Ambiental, a student movement which began to protest about the lack of democracy in the media during the Peña Nieto presidential campaign. The Unión de Cientificos Comprometidos con la Sociedad also presented the newly elected president Enrique Peña Nieto (PRI) with a letter bearing over 3,000 signatures from scientists and experts against the introduction of GM maize in Mexico. In September 2013 a judge in Mexico City responded to the lawsuit brought by

Acción Colectiva, an NGO encompassing 53 scientists and 22 civil organisations, and ordered that the Ministries of Agriculture (SAGARPA) and the Environment (SEMARNAT) immediately suspend the granting of permits for commercial cultivation of GM maize in the whole country. In his ruling he cited UN's Global Compact Principle 7, which states that 'Businesses should support a precautionary approach to environmental challenges' (UN Global Compact 2013). This ruling is being hotly debated, and both the federal government and Monsanto have challenged the court decision through more than 48 lawsuits to date.

More recently, in March 2014, a judge in the State of Campeche, in southern Mexico, granted an injunction to Maya communities and to honey producers against permits given by SAGARPA and SEMARNAT for the commercial cultivation of GM soya in their territories. The ruling was based on the violation of legal procedures on the part of both SAGARPA and SEMARNAT, as SAGARPA had not held a free and informed consultation among indigenous communities prior to the issuing of permits for the planting of GM soya in their lands; and since SEMARNAT had failed to take into account binding reports by CONABIO, CONANP (National Commission for Protected Natural Areas) and INE which had advised against the cultivation of GM soy in the area. During 2014, Monsanto, PHI Mexico, and Dow Agroscience continued their commercial and legal campaigns, despite the provisional suspension of permits for GM maize cultivation ordered by a judge in 2013, and which was later ratified by another court's resolution. There is also a continuation of public resistance to other GM crops aside from maize, a resistance which is increasingly performed through the courts and by rural producers, of which honey producers from Yucatán are a prominent example (Moguel 2014). In the meantime, the federal government seems to have embarked in an open campaign supporting the speedy introduction of GM crops in the country. Recently, the Coordinator of Science, Technology and Innovation of the Presidency stated that his department was gathering scientific evidence to prove the low risk of GM crops, in order to accelerate their extensive implementation in the country in the context of the new agrarian reform announced by President Peña Nieto in January 2014 (Paz Avendaño 2014). Such plans for the extensive cultivation of GM crops (including maize) could be seen as one strategic aspect of an increasingly neoliberal agricultural policy which is determining the future of the Mexican countryside (Ramos and Rodríguez 2014; Román 2014). Also in 2014, SAGARPA enforced the labelling of GM seeds for agricultural production (Pérez 2014) and, in June, the state of Morelos issued a regional law prohibiting the cultivation of GM maize in its territory and promoting the cultivation of local landraces (Martínez 2014; Morelos 2014).

As this commentary demonstrates, the recent acts in the story of the GM maize controversy in Mexico are ongoing, and are symptomatic of deep divisions that permeate different state institutions on GM maize, the spill-over of the issue of GM maize to other GM crops and products, the continuing lack of a long-demanded social and political agreement between the government, the scientific community, and the general public on this issue, the determination of the federal government to promote the approval and widespread adoption of GM crops despite public opposition, and the increasing role of the judiciary in the political battle between opponents of GM crops and government and industry actors.

TABLE 2.1 GM crops in Mexico: chronology of events

Date	*Event*
1970s	Agricultural policy in Mexico is governed by a dominant policy narrative of seeking self-sufficiency in basic food grains.
1982	Following the debt crisis, a new policy narrative is developed, centred on trade liberalisation, privatisation and the reduction of subsidies for smallholder agriculture.
1988	The General Directorate of Plant Health (DGSV), at the Ministry of Agriculture, begins to grant permits for scientific field trials of GM crops, advised by an ad hoc committee of scientists and government agencies.
1998	DGSV imposes a de facto moratorium on GM maize field trials, arguing that GM maize trails are of little economic benefit to Mexico, and that GM maize poses significant risk of mixing with landraces.
1999	Greenpeace discovers GM maize in a cargo of maize being shipped from the US to Veracruz which leads to a vociferous anti-GM campaign. A group of concerned scientists calls for more effective regulation of GM crops, which leads to the establishment of the Inter-Ministerial Committee on Biosafety (CIBIOGEM) in 2002.
2001	Berkeley scientists Ignacio Quist and David Chapela publish an article in *Nature*, stating that they had discovered the cauliflower mosaic virus, used in most transgenic crops, in native maize fields in Oaxaca. The article receives much criticism from certain sectors of the scientific community, and the journal withdraws its support for it.
2002	The first broad anti-GM maize coalition is formed, comprising activists, farmers, academics, indigenous groups and NGOs, all of whom attend the forum En Defensa del Maiz in Mexico City. The debate on GM shifts from technical considerations of gene flow to wider social issues.
2004	The Committee for Environmental Cooperation, linked to NAFTA, issues a report claiming transgenic contamination of maize in Oaxaca.
2005	The Mexican Biosafety Law is approved. This bill is opposed by NGOs due to a perceived lack of transparency in the deliberation process.
2006	The first round of applications for GM field trials are submitted, although they are immediately suspended because of questions about their legality. The seed companies initiate a campaign of public engagement on maize.
2008	The special protection of maize within NAFTA comes to an end. Mexico City declares itself GM-free zone.
2009	The Regime for the Special Protection for Maize becomes active, and a dedicated public laboratory is created to detect, identify and quantify GM maize. Local state laws for the protection of local landraces of maize come into force in Tlaxcala and Michoacán.

TABLE 2.1 continued

Date	*Event*
2012	A new Agreement for the Centres of Origin and Genetic Biodiversity of Maize is approved, which declares that large areas of the eight northern states can legitimately be planted with GM maize.
2013	The first round of permits for the cultivation of GM maize in the northern states under the 2012 Agreement are suspended by a judge's ruling. This leads to a number of court actions from the seed companies and the state.
2014	Court injunctions on GM soja are imposed in Yucatán. The labelling of GM seeds for agricultural production is enforced by SAGARPA. A law barring the cultivation of GM maize in the state of Morelos comes into force.

The field ethnography

The ethnographic fieldwork in Mexico was conducted in the Pátzcuaro Lake area, in the state of Michoacán. The research was carried out in a predominantly indigenous community between September and December 2012, and involved a period of participant observation with smallholder farmers and women who were involved in the making and selling of maize tortillas, alongside some participation in community and agricultural activities and a set of interviews with local people. The ethnography involved spending time with tortilla sellers at regional markets, where local customers were also interviewed, and participating in other maize-related activities in the region (such as religious festivals or political meetings), where the researchers carried out interviews.

The Pátzcuaro Lake region is home to a number of strongly interconnected indigenous Purhépecha and non-indigenous rural communities, both of whom are economically and socially connected to the regional urban centre of Pátzcuaro. Many people in these rural communities practise smallholder rain-fed native maize agriculture through the milpa system. Milpa is the term used to designate both a plot of land and the specific system of cultivation which takes place in it. This system of pre-Hispanic origin consists in combining up to 60 different plants, including diverse maize types, beans, squash, chilli, tomato, and some edible weeds in the same small plot (Toledo *et al.* 2013), in order to produce enough food to fulfil the nutritional needs of the kin group, while conserving the soil properties from season to season. Smallholder farmers also plant some hybrid maize in some of their plots. Maize production is mainly for home consumption, but excess is sold to neighbours or at the local markets. Farmers own their seed and exchange it within the communities for seed improvement. Most agricultural land in the area is communal, either in the form of *ejidos* (rural properties for collective use, originally owned by the state, established after the Mexican revolution) or *bienes comunales*, collectively owned land connected to indigenous communities.

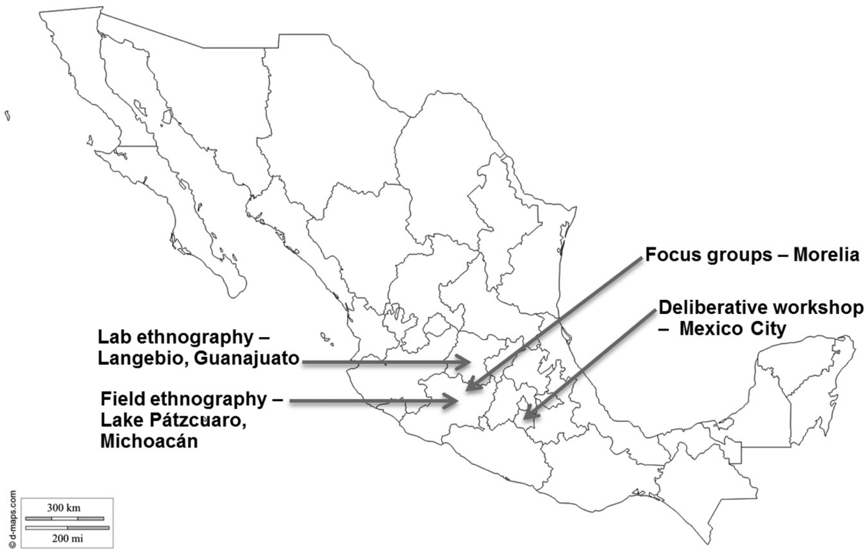

FIGURE 2.1 Map of fieldwork sites in Mexico

Source: http://d-maps.com/m/america/mexico/mexique/mexique34.gif

Michoacán is suffering the effects of the crisis that has affected many of the rural areas in the centre and south of Mexico, made worse by changing global economic conditions. Fewer people are practising agriculture, as young men and women move increasingly to cities, or migrate to the northern states or to the USA for work. The demise of rural subsidies, the increase in input prices, as well as competition from imported cheap grains, impoverished soil conditions, and climate change are impacting increasingly on smallholder farmers. Thus agriculture is rarely nowadays the sole source of income for people in the region. Households increasingly develop hybrid economic strategies that include the commercialisation of handmade crafts (such as straw hats or embroidered clothing) and temporary paid labour (construction work for men, or domestic work for women). This is also a region where drug trafficking has had a significant impact at the local level, and mafia-related violence in the communities is affecting all aspects of quotidian life. However native maize agriculture remains important in Michoacán, and it still takes up 50 per cent of all agricultural land in the state. In recent times, and due to more stringent migration laws and controls being implemented in the USA, many former migrants are returning to their communities, and some of them are turning back to traditional maize agriculture in their family plots as a readily available form of subsistence.

The significance of native maize in rural communities

Native maize as local economic strategy

The family milpa is seldom nowadays able to sustain a whole family economically.[1] However, it does in many cases produce enough maize and other vegetables (squash, beans, and chillies) to feed the household for most of the year, with any excess production sold on to neighbours or at regional markets for cash. In the lakeside communities of the Pátzcuaro area, where agricultural land is scarce, the milpa has rarely been the sole source of income for families. People have also fished in the lake, kept animals such as chicken or pigs, and produced different types of crafts for sale (from pottery to wooden masks) since the times of the colony. Nowadays, paid labour and the remittances from migrants are likely to subsidise the keeping and running of the household's milpa.

However, and despite the fact that these days it might be cheaper to buy hybrid maize in the shop than to grow your own criollo varieties, maize continues to be seen by rural people as a kind of insurance against hunger (Fitting 2011), and native maize from the family milpa is nearly always the preferred choice for household consumption. Furthermore, for vulnerable sectors of the rural population (such as old people or single mothers) cultivating one's own maize on one's own land, and cooking associated maize food products for sale, has often become a much needed strategy for viable economic survival. In the region, many women who made native maize food products for sale were organised in a small cooperative known as Red Tsiri (*tsiri* means maize in Purhépecha) which commercialised traditional and organic foodstuffs at the nearby urban centres with reasonable success, helped by the rising interest in organic and traditional foods among the Mexican urban middle classes.

Criollo seeds and milpas as property and resources

In rural communities in the area of our study, as in many other parts of rural Mexico, native maize seeds are very special items. They belong to the household, but most specifically to the farming unit, commonly of husband and wife, who tend to make joint decisions about what to grow each year. They can be considered as family heirlooms, passed down from parents to children together with agricultural training and wisdom, and identified and referred to as 'my father's' or even 'my grandfather's' seeds. Seeds are exchanged between relatives and neighbours each year, but seed exchanges occur between farmers only in relationships of mutual trust, in the sense that they need to trust each other's farming practices, the quality and strength of their seeds and their honourable intentions within the exchange. In short, seeds are important and valued properties, which carry traditional family knowledge and good practice from one generation to the next; they also are, together with land, the main agricultural capital of smallholder farmers, the assets which guarantee that they will be able to plant and grow maize from year to year and thus survive. In addition, it is now widely accepted that seed exchange is one of the best forms of in situ agricultural biodiversity conservation (Calvet-Mir *et al*. 2012).

Land is the other type of agricultural resource which holds a special significance among smallholder farmers who continue to practise traditional maize agriculture. Like seeds, the milpa is passed down from parent to child, and is linked to a specific family or household. The family milpa is not seen simply as an agricultural asset in terms of production, but is connected with memories from childhood, with kin and village identity, with work but also with leisure. Local people still consider that selling one's milpa, particularly to outsiders who will (probably) not use it for its traditional purpose, is morally wrong. Even nowadays, when the importance of maize agriculture has receded in economic terms, and when young people are migrating away from the countryside, those household members who remain in the communities (grandparents, parents, wives, siblings and children) still tend to keep and cultivate the family milpa. One example of this practice found in our study was that of a qualified nurse in one of the indigenous communities; her two daughters held university degrees and lived in the nearby state capital, but she still preserved her family land and cultivated native maize with the help of paid workers.

The social and cultural significance of maize agriculture

In small rural communities around Lake Pátzcuaro, smallholder, rain-fed maize agriculture, practised by both indigenous and non-indigenous communities, continues to be an important activity around which collective social relations and collective life pivot. People within the community in our research share and exchange criollo maize seeds between relatives and neighbours in relational networks of 'trust'. Maize is commonly 'borrowed' from family or friends in times of scarcity, and returned the following year, when it is others who may be in need. In most life cycle and community celebrations, maize food, specific for each occasion, is collectively prepared by the women, and exchanged between households as a form of expressing and maintaining relationships between kin groups, neighbourhoods and even nearby communities. Certain types of special maize foods are prepared to care for people at particular moments of their lives: for instance, thick tortillas are given to children to make them grow strong, and white atole is prepared for first time mothers to help them breastfeed their newborn babies. In many religious festivals, maize is offered to the saints in thanks for a good harvest, and cobs are gifted to the attending public to signify pride in agricultural production and gratitude from the village's inhabitants. Thus it could be argued that maize fuels and sustains networks of social relations of trust, support and exchange, in communities where a key form of 'social security' comes from these forms of networking and relating, and where many other components of community life (knowledge and information, but also money and goods) also flow through these networks.

Maize agriculture as identity

Many of the smallholder farmers interviewed in the study (mostly men, but also some women), reported experiencing a sense of pride and pleasure in the conduct of their agricultural practices. They spoke about cultivating criollo maize 'for pleasure' or 'enjoyment' and not (simply) for 'business', and described the activity more like a craft than a simple pecuniary set of exchanges:

> For me, growing maize is a pleasure, holding the cobs, beautiful cobs, make one happy, gathering the seed, looking at well-formed plants, at the harvest …
>
> *(Smallholder maize farmer, Tzurumútaro)*

They also talked about the empirical dimension of their agricultural labour, which is often driven by an experimental curiosity:

> I had some seed of mine, but I did not plant that because I wanted to see how this other one worked. I had spent a couple of years without planting anything, and now I wanted to see if it was true that this one yielded much more maize and of better quality. I would like to experiment more to see how it goes.
>
> *(Smallholder maize farmer, Puácuaro)*

Good, dedicated, successful farmers are recognised and respected in their communities, and they are the ones who are most sought after for seed exchange. In addition, different farming styles are attributed to different communities, thus linking forms of maize agriculture to local and regional identities. In short, what became highly evident as a research finding, is that the social practices involved and invested in milpa agriculture and know-how, and in people's experience, were highly integrated with moral, ethical and aesthetic notions about what constitutes a good life. Agricultural practice goes beyond mere task to embrace an artisan's dedication, providing people with a strong sense of personal, social and cultural identity, as well as enabling farmers in very restricted economic circumstances to experience aesthetic and spiritual pleasures and the satisfaction of a job well done.

Smallholder farmers' perceptions of GM maize

Smallholder producers in the Pátzcuaro Lake area reported a lack of knowledge about GM crops and foods as well as in the technological processes implicated in genetic modification; something they shared with many other sectors of the population. They complained about the absence of neutral and reliable information on genetically modified organisms in general and GM maize in particular. Furthermore, many people in rural areas had the suspicion that this lack of information may be a deliberate strategy on the part of the federal government to keep them oblivious of their real intentions, which many perceived as that of quietly introducing GM maize without public consultation or consent. It is necessary to note here that commercial cultivation of GM maize has not taken place yet in the region. Despite the fact that GM maize is not yet cultivated, or even authorised in the area, many smallholder producers, both male and female, had heard about a 'new' maize which is 'made in laboratories'. They reported a degree of understanding along with ideas and concerns about what they felt would more than likely become an impending reality. These worries and perceptions are categorised using the headings below.

Unknown dangers and ontological rejections

Farmers expressed concern with proposed varieties of GM maize seed, which were seen as likely to be coming their way, over what precisely GM maize is and how it would work in terms of agricultural practice. This suspicion of 'trouble' hinged upon two factors: first, that GM seeds would originate entirely from 'outside' the communities and the rural farming environment which they know and trust. Second, that GM seeds would be researched, developed, regulated and distributed by organisations and institutions towards which there has been a historical lack of trust, such as multinational seed companies and the federal government. Many farmers also perceived GM maize as an artificial, man-made construct:

> In a public talk, I heard about that maize which is made in laboratories, transgenesis or something like that …
>
> *(Smallholder maize farmer, Uricho)*

Smallholder producers communicated a sense of mistrust in the processes and forms of intervention that are used to create GM maize in the labs, which was evident in the often-posed question: 'what are they going to do to our maize? Some of them reported telling their neighbours not to give away native maize seeds to unknown people (presumably scientists or seed company representatives), who had visited their communities with that request, assuming their intentions were not to be trusted nor would they be for the common good. Their preoccupation was not only about the fate of maize seeds in laboratories, but also more generally about the long-term fate of 'their' maize.

Mistrust in government, public institutions and seed companies

Smallholder producers conveyed an implicit lack of trust in those they saw as the main proponents of GM maize: the government as an institution, politicians as a social group, and the agricultural and biotechnology industries as interested parties. They had the suspicion that GM maize may not be grown for human consumption or even animal feed, but for biofuels for export to developed countries. They also deduced that GM maize seeds would not be exchangeable, as they are now, but would need to be bought from the seed companies each year, something they suggested would be outside their economic possibilities. Moreover they suspected that the real reason behind the drive for GM maize is the promise of benefit for the usual constituencies, which are, according to our respondents, the national and multinationals companies owned by or operating in the interests of the rich and powerful, and the corrupt politicians which favour them in exchange for bribes. Both interpretations of GM maize (suspicious as an object in itself or because of its hidden intentionality) clearly relate to a comprehensive, experientially felt and historically informed lack of trust in the federal government, which was nearly universally perceived as incapable of defending citizens' interests and which was presumed to operate almost exclusively in favour of global economic actors. There were two fundamental questions which often appeared in exchanges with farmers: 'What is GM maize for?' and 'How can we defend ourselves?'. The first question refers to the motives behind the proposed cultivation of GM maize in Mexico, and asks whether it is genuinely needed from the perspective of traditional smallholder agriculture:

> Why change our seed? We are using and benefiting from our grandparents maize, and it is that same maize that we can continue planting …
>
> *(Smallholder maize farmer, Napízaro)*

The second question is linked to the fear of what was perceived to be yet another 'imposition from above', which could have negative consequences not only for the preservation of their criollo maize, but also for their ownership of seeds and land as resources and for the survival of their chosen ways of life and agricultural practices.

Interviews with stakeholders

The stakeholder interviews for the Mexican case study were carried out in Spanish at different locations in Morelia, Lake Pátzcuaro, Irapuato and Mexico City. Here, we present the results of the stakeholder responses under a series of significant thematic headings.

The state of the Mexican countryside

Most stakeholders agreed that the Mexican countryside was in a state of crisis. Evidence was provided by referring to current processes of out-migration, the abandonment of traditional agriculture in favour of lowly paid urban employment, increasing poverty among smallholder farmers and the lack of employment opportunities for young people in rural areas.

> [The Mexican countryside] needs attention, so that it produces food, not migrants.
>
> *(Religious stakeholder)*

Most interviewees agreed on the conditions that had caused this situation. They commonly identified the Mexican government as responsible for 'abandoning' the countryside and its smallholder populations. They believed this has been exacerbated through the implementation of neoliberal rural policies which had included reductions in agricultural subsidies and changes in land ownership laws. Many also blamed international policy and treaties such as NAFTA for this situation; they argued that global economic models were forcing Mexican agriculture towards increasing industrialisation and monetisation. International policy and treaties were seen to have created a situation of dependency on food imports, which was seen as not conducive to food security and food sovereignty. The majority of stakeholders considered this to be the result of previous Mexican government policies that had embraced a neoliberal economic and political model, which they saw as being exacerbated in the present 6-year presidential period of PRI's Peña Nieto.

Conversely, there are some respondents who blamed the rural crisis not on neoliberal policies aimed at free trade and market liberalisation, but precisely on a lack of adoption and implementation of such policies by successive Mexican governments. Representatives of seed companies and largeholder farmers' associations adopted what can be considered a developmentalist and economicist perspective on rural development: they considered the fundamental problem in the countryside as one of residual 'backwardness', and as being sustained by an ongoing lack of access to agricultural technologies and education, as well as from inadequate infrastructure. These stakeholders highlighted the need for increases in grain production, in terms of volume, in order for Mexico to become more competitive in international markets. They also blamed the federal government for being 'slow' in catching up with agricultural biotechnology.

One aspect to note is the generalised vision of a country divided in two distinct areas: the North (states of Sonora, Sinaloa, Chihuahua, Coahuila, Durango and Nuevo León in particular) versus the Centre and the South (roughly the rest of the states). Those two areas have different forms of agriculture (large-scale, intensive and export-oriented in the North; smallholder, traditional and to a large extent for local consumption in the South), which are accompanied with what stakeholders see as ideological differences at state-level governments, policies and populations. This division can be seen in the ways in which Mexican government policy has been developed with respect to native maize centres of origin.

Opinions about GM maize

Most people interviewed (with the exception of the representatives of smallholder farmers and of women's associations) were reasonably knowledgeable about GM crop technologies from a scientific perspective. It is worth noting that 8 out of 12 interviewed stakeholders held science degrees in different disciplines. Smallholder farmers and women's associations reported having heard about GMOs ('seeds genetically modified in labs') but also reported other ideas about them which would not be identified as scientifically accurate by other actors, but which are very significant for these groups:

> Foreign maize, not for human consumption … We do not know it … it is contaminated with products … there is the danger that it can contaminate land, maize, fruit, and this passes to the human food chain.
>
> *(Smallholder producer)*

Moreover, smallholder farmers and women's associations' opinions about GMOs reflected more their understanding of the political economy surrounding GM agricultural development and commercialisation in Mexico than technical considerations. They considered that GM crops are produced by big companies who are predominantly concerned with sales rather than with the conservation of biodiversity or with genetic contamination or the quality of the product:

> GM favours big groups and their economic interests, and harms rural communities.
>
> *(Women's association representative)*

In addition, most respondents differentiated between the case of GM maize and other GM crops in Mexico. There are various reasons for this distinction. First, most people recognised the fact that Mexico is the centre of origin and diversity of maize, and that this represents a serious and collective responsibility with regards to biodiversity conservation. This concern with the preservation of native maize biodiversity was linked to a broad distrust in the current regulatory system and its capacity to guarantee biosafety. Many stakeholders were of the opinion that GM maize cannot coexist with non-GM at present, because of the clear (and not successfully refuted) risk of contamination.

> It is not by chance that it [maize] is the only species which is specifically mentioned in the Biosafety Law.
>
> *(Regulator)*

Second, respondents highlighted the significance of maize for rural economies and for traditional forms of agriculture.[2] Many of them spoke of the potential lack of benefits of GM maize for smallholder producers due to the impossibility of keeping and exchanging seeds, which would be seen as both an economic and a cultural loss ('it goes against the Mexican culture of maize', religious stakeholder). Some interviewees stated that the pressure to introduce GM maize in Mexico had been promoted on purely an economic basis, and that its adoption would benefit mainly largeholder farmers, multinational seed companies and other large-scale agricultural farming and food consortiums. A few pointed to studies which showed evidence of a decrease in productivity of GM crops over time. Third, native maize was perceived not simply as a commodity or a crop; it was recognised, even by scientists and regulators, as having a far broader impact and significance in Mexican history, society and culture:

> Maize is basic in Mexican food and culture.
>
> *(Social scientist)*

> Maize should not be modified in its nutritional properties because of the way we consume it, and the way we use it on a daily basis.
>
> *(Regulator)*

Aside from specific concerns relating to GM maize, one respondent revealed a set of ontological arguments against GM crops, which were also implicit in the arguments of other stakeholders' (particularly among consumer representatives and some scientists): they considered that agricultural GMOs are different in kind from medical GMOs, because the latter stay in the laboratory, while the former are unleashed in the fields, and thus are harder to control or contain. GM crops, and particularly those which involve the introgression of genes from other species, were rejected on an ontological and ethical basis, commonly using arguments that such highly interventionist scientific practices would go against nature in important ways:

> I think human beings have a very arrogant attitude towards nature, they want to control it to the last resort. [GM] technology can break barriers that nature has imposed for over millions of years. They were created so that there was not genetic recombination from different groups, kingdoms and genera … This has to be for a reason, an evolutionary reason for species conservation. The moment human beings break those barriers, we are attempting to move against evolutionary dynamics.
>
> *(Consumer association's representative)*

Seed companies and largeholder farmers' representatives shared a more positive vision of GM maize. They considered that it could be beneficial for certain parts of the country (especially the North) and that it could contribute towards improved food security as well as to helping resolve the ongoing crisis in agriculture. The representatives of seed companies defended the argument, shared by many scientists, that GM crop technologies represent a continuum from traditional forms of plant breeding, rather than a qualitative change:

> We have domesticated plants and they depend on us … But there's a point in which we find [genetic] limitations within the same species, we cannot find genes for introjection … So the possibility of incorporating biological functions through genetic modification is a great discovery. It is possible to make human proteins within bacteria, which means that bacteria keep the same fundamental mechanisms of gene expression as humans, and vice versa.
>
> *(Seed company representative)*

GM maize debates and policy

The majority of stakeholders believed that the GM maize debate in Mexico is not resolved, yet was somewhat foreclosed by certain recent decisions of Mexican deputies (MPs):

> [The debate] was curtailed by federal government decisions, as we found out at Davos in 2010 … We spoke to the Coordinator for Advisers to the Presidency … and he told us that President Calderón had just spoken to Monsanto's President and that [Calderón] had promised him to unlock the possibility of growing GM maize in Mexico. Whilst we are here debating, the Mexican government was taking a political decision, responding to financial interests.
>
> *(Religious organisations' representative)*

There was a generalised agreement by a number of our respondents that the current Biosafety Law (approved in 2005 and popularly known as 'Monsanto Law) does not adequately protect GM maize, but rather favours GM implementation in general. By contrast, the seed company representatives viewed the Biosafety Law as a good instrument for regulation, and as opening the path for GM maize approvals. One argument that seed companies share with regulators is that GM maize is already in Mexico in the form of imported grain from the United States and Canada as permitted by the NAFTA agreement, and that properly regulated Mexican-grown GM maize would be a better and safer option.

Most respondents shared similar concerns about the nature and dynamics of the current debate on GM maize in Mexico. They spoke of the lack of reliable and unbiased information, of the lack of transparency in deliberation and policy-making and of the lack of meaningful public participation. They commonly blamed the federal government for this situation, and considered the GM crop debate as emblematic of wider problems of Mexican political culture: of a government that is all too often corrupt, that bases its decisions on the economic interests for the few and that has little sense of governing in the public interest. Many stakeholders believed that the lack of transparency and of institutional procedures for public participation were in fact governmental tactics designed to speedily approve, promote and adopt GM crops in line with their interests, narrowly defined. Most stakeholders shared a sense of impotence in this respect, as they felt that so-called public debates were not genuine or meaningful, since actors were not really listened to:

> Maize's Special Protection Regime was consulted, thousands of opinions were received online, but they [the government] never took them into account. There are thousands of expressed opinions when permits [are about to be issued], but they do not take them into account. So why participate, what for? There is no real debate, no real participation which has an impact and where you can see results.
>
> *(NGO representative)*

The seed companies' representative also felt that debates were one-sided, but in the opposite direction, and reported that 'there is not debate, but controversy'. There were, according to this stakeholder, three distinct elements to the debate on GM crops in Mexico: relating to maize, cotton and soya. GM soya was represented as a silent issue until 'the business about honey' (when honey producers from Yucatán found that their honey was not accepted as organic in the EU market anymore):

> Europeans were happily eating honey and they did not care, but then they developed an 'absurd regulation' saying that pollen is an item that has to be analysed as if it was a GMO, even if it did not represent a problem of biosafety.
> *(Seed companies' representative)*

Around a third of respondents stated that indigenous groups should have special rights on the issue of GM maize, on the basis of considerations of human rights, sovereignty over resources, biosafety and political economy:

> [Indigenous peoples have the] right to preserve biological integrity, the purity of the (maize) landraces, to avoid mechanisms of IP control, to keep their genetic resources, their seeds and their crops away from transgenes.
> *(Indigenous groups' representative)*

In a similar vein, a number of respondents argued that the debates on GM maize in Mexico had been dominated by scientific reductionism, and that in the particular case of maize, not enough attention has been given to social or cultural aspects. The regulator, for example, remarked that there should be more concern with the ways in which traditional agricultural practices contribute to maize biodiversity conservation, and that the discussion should also incorporate issues such as loss of knowledge, practices and skills among rural populations.

Voices in debates on GM crops and on regulation

There was a general agreement that the voices that are 'least heard' in GM crop debates in Mexico are those of consumers, smallholder farmers and indigenous groups. Consumers were seen as a heterogeneous group which lacks a unified voice or a strong presence. According to the seed companies' representative:

> They do not have a militant attitude, they want to have quality products which are more accessible, safer, and they want to know that the relevant authorities who generate that safety and certainty, such as COFEPRIS, do their job properly.
> *(Seed companies' representative)*

Other stakeholders preferred to talk of 'citizens', or 'civil society' to refer to the majority of the population, who might not have a clear position for or against GM crops and foods, or who may not have a scientifically informed perspective of the issue, yet who nonetheless have a stake in it. Smallholder farmers were widely recognised as an absent voice in GM crop debates, although most respondents thought they should be included because 'they are the ones who grow the maize'. The category 'smallholder farmers' is often identified with that of 'indigenous groups', as rural indigenous populations are strongly associated with traditional maize agriculture in Mexico. Indigenous people represent 14.9 per cent of Mexico's total population (15.7 million out of 118 million inhabitants in 2013). They are perceived as key voices with respect to genetic resources and biodiversity conservation, yet according to a number of our respondents they had not been adequately or systematically consulted on GM maize.

Another voice which was reported as absent in debates on GM maize was that of the independent, neutral scientist, who was contrasted with those scientists who were seen as compromised through collaboration with the biotechnology industry. Those respondents who advocated the need to implement GM maize in Mexico tended to argue from within a 'sound science' rhetoric: namely, that debates on the approval, governance and uptake of GM maize should be guided primarily (for some purely) by appraising scientific evidence of risks to the environment and human health rather than through a consideration of political, cultural or ethical factors. According to these respondents, sound science has provided sufficient evidence to prove (in the absence of evidence to the contrary) that GM maize is innocuous and bio-safe.

Other voices who were noted as relevant actors in our interviews with stakeholders, were those of the government, which was represented as largely inactive in debates on regulation. In addition, the voices of certain NGOs (such as Greenpeace) were perceived as problematic, and variably described as 'a caricature, contrary', 'too militant', and 'lacking in solid arguments'. As to who were the most vocally heard voices in the debate, the majority of respondents presented the view that the biotechnology industry has been most successful in making its voice heard and in actively shaping agricultural GM policy and regulation. Even the seed companies' representative agreed that large companies and consortiums had been successful in making themselves heard at governmental and congress level, had successfully promoted the development of agricultural biotechnology and 'had achieved regulation [*sic*]'. While the seed companies viewed this as a positive achievement, the other stakeholders were overtly critical of these methods:

> They want to get things changed by putting pressure on the regulatory system. It is sad that companies that could be more organised, more responsible, want to get to the commercial phases in a hurry, and do not assume responsibility about their management.
>
> *(Regulator)*

The clear majority of our respondents shared the view that the Mexican media had tended to support the agri-food and biotechnology industries, and their associated discourses, in an unquestioning manner, using such arguments as 'we are falling behind in technology', 'it is necessary for Mexico to participate in international agreements and to adopt GM crops', 'the Mexican countryside needs biotechnology', and so on. Most of our respondents considered these arguments are far too simplistic. Interestingly, largeholder agricultural producers viewed themselves as absent in the debate and as being insufficiently consulted. Their claim was that their voice, advocating their right to choose to grow GM maize, should be heard and respected:

> We need to act a bit stronger from the legislative perspective … they [the government] should take producers opinions into account.
>
> *(Largeholder farmers' representative)*

GM governance and decision-making

Most respondents perceived a distinct lack of formal and institutional spaces for citizens' participation in decision-making on GM crops. Public participation, they say, should be enshrined in policy, and citizen movements should demand participation and democracy. Interestingly, the majority of interviewed stakeholders considered that decisions about GM crops should continue to be made in the same forums where they are made at present:

> The place [where decisions] are being made is fine, the problem is how those decisions are taken, and who is being taken into account … The problem is that only one side is being listened to, because of their economic and political power.
>
> *(Regulator)*

Most stakeholders agreed that current practices of policy-making and regulation on GM crops 'are not examples of a process of real, participative, representative democracy' (social scientist). Many viewed corruption as evident both in the process and in the people responsible for legislation and policy-making. For this reason, a large number of our respondents argued that economically powerful consortiums should not be included in decision-making processes at a governmental level, as they can (and do) influence political decisions through their economic power. Stakeholders, however, recognised the complexity of existing regulatory systems and frameworks in Mexico on GM crops. The regulator respondent pointed out that there is a lack of capacity and resources in government, and that there are serious differences of opinion even within the same governmental departments and agencies that take the decisions on GM maize. According to this insider's perspective, SAGARPA (the Ministry of Agriculture) supports the interests of largeholder farmers, while SEMARNAT (the Ministry for the Environment) adopts a more precautionary position. Even though SEMARNAT's reports are meant to be binding within the internal consultation process on GM crop permits, contrary decisions are taken at other levels and many times final decisions are taken for political, not technical, reasons.

Finally, there was a general call for the implementation of more and better methods of public consultation and participation, particularly for those groups which have to date been marginalised in current debates and policy-making on GM maize:

> In the last presidential term, there was an initiative for a consultation law for indigenous peoples. We participated with comments, saying 'we should consult and respect their practices, they should express whatever they have to say'. It is very legitimate to say I want that, or I don't want that [this law was not passed].
>
> *(Regulator)*

Seed company representatives, however, argued that existing consultations mechanisms were more than sufficient. They referred to the present mechanism of public consultation for GM permits, which gives the public 20 days to present evidence of harms, and which have to be scientifically and technically substantiated to be legitimate.

Ethnography at a research laboratory

Our ethnographic research took place at Langebio, the National Laboratory of Genomics for Biodiversity, in Guanajuato, Mexico. The research was conducted across three continuous weeks, and included participant observation, in-depth semi-structured interviews, and secondary data collection on the operation of the unit. Langebio was created in 2005 as part of CINVESTAV, the Centre for Research and Advanced Studies of the National Polytechnic Institute (IPN), a respected public university in Mexico. It came into existence thanks to an agreement between the Federal Ministry of Education (SEP), the Ministry of Agriculture (SAGARPA), the National Research and Technology Council (CONACyT), the Government of the State of Guanajuato and CINVESTAV itself. The aim of Langebio is, according to its director, Dr Luis Herrera-Estrella, 'to bring together interdisciplinary groups to carry out cutting-edge research and to generate genetic knowledge about Mexican biodiversity that could lead to its sustainable use' (Herrera-Estrella no date). On the centre's webpage, Dr Herrera-Estrella explains that the foundation of the laboratory responded to a previous lack of human and material resources to carry out genome sequencing and functional analysis of complex genomes in order to both characterise Mexican biodiversity and 'explore potential applications' for medicine, agriculture and industry.

Within Langebio, some researchers worked closely with Dr Ruairidh Sawers's team, the Maize Genetics and Genomics group. The broad aim of their research was to explore genetic variation in landrace maize in order to offer new insights and possibilities for 'conferring tolerance to both biotic and abiotic stress not currently available to breeding programs' (Sawers no date). At the time of study (2013), the major focus of investigation was on the tolerance of maize to phosphate stress. Under the direction of Dr Sawers, the team encompassed various postdoctoral, doctoral and master's researchers, all of whom agreed to participate in our project. In addition, the laboratory's director and other research team leaders were interviewed, in response to their request for an opportunity to express their views on GMOs for our project. A total of 16 senior and junior researchers participated in our study, and 5 of them were interviewed in depth. For the purposes of analysis of the scientific visions and voices in the project, we will also include in this section the material from two stakeholder structured interviews, both of them involving internationally renowned molecular biologists and plant geneticists. Both interviews were carried out outside the confines of the laboratory.

From the analysis of our research in the laboratory and from the interviews with scientists, two distinct scientific framings of the GM crop issue emerge, as exemplified in the responses of our key scientific stakeholders. On the one hand, one section of the scientific and academic community supports an agro-ecological approach to seeds and crops, considering them as integral parts of complex systems of human–environment interactions. From this systemic perspective, it was not possible to consider GM seeds and crops in isolation from the social, cultural, economic or political contexts within which they emerge and are put to use. Thus many scientists who hold this framing see GMOs as 'bio-technological, techno-scientific artifacts' which are being rhetorically presented as 'magic bullets' (according to an expert in molecular genetics and plant biology we interviewed). Yet, according to this agro-ecological vision, in their current formats they are highly unlikely to resolve hunger or poverty,[3] benefit smallholder farmers, or promote social justice and sustainability. Representatives of this approach, including some highly respected molecular biologists and plant geneticists embrace the precautionary principle with regards to GMOs and thus propose the continuation of research only within the containment of the laboratory until existing doubts and problems are resolved. For them, and in the particular case of GM maize, there are too many unquantifiable risks to its experimental or commercial implementation, too many unknown consequences of its release to the environment which could be irreversible and potentially fatal for native maize biodiversity, and too many social and economic implications for traditional agricultural systems.

On the other hand, our research identified an alternative biotechnological vision in which GM seeds and crops are seen as separated from social or political contexts: they are non-relational, unique scientific objects which are created by well-intentioned academics and professionals in the context of neutral scientific and technological domains (the laboratories). Many scientists who think along these lines believe that the fate of techno-scientific creations outside the laboratory escapes their control, and thus their responsibility. The molecular biologists and plant geneticists who situate themselves within this frame tend to be nevertheless convinced of the effectivity and safety of GMOs and defend their release to the environment, where they foresee little substantial risk, harm or unknown consequences inbuilt in the GM crops themselves that cannot be identified in advance through existing processes of regulation and governance. In the case of GM maize, according to this perspective, even if cross-pollination were to occur with native varieties, this might nevertheless be seen as a positive event, which would contribute to the maintenance, not demise, of the species biodiversity. Scientists who hold this vision tend to express frustration by the lack of progress in the approval and implementation of GM maize, and concern about the loss of competitiveness of Mexico in the international biotechnological race. Interestingly, many recognise that, at present, GM crop technology benefits mostly largeholder farmers, but blame this on a lack of political will to facilitate their adoption among smallholder farmers. They also believe that the intricate and expensive Mexican regulatory processes for GM maize benefit the global seed companies such as Monsanto, and damage the development of an endogenous national public biotechnology research capability and industry. Many of these scientists also support a pragmatic approach to GM crops, since GMOs are 'already here' (according to an expert in physiology and metabolic engineering of plants).

There are, however, many points of convergence between these apparently antagonistic scientific views of GM crops in general and GM maize in particular. Both paradigmatic perspectives recognise a hierarchy of experts and arguments in the GM crop debate in Mexico, where techno-scientific voices and conclusions are seen as needing to be given priority over non-scientific arguments. In addition, both sides cite 'independence' as the most important characteristic of a 'sound science' approach, although their interpretation of what this concept means varies. For the agro-ecological group, 'independence' means that neither scientists nor their findings should be influenced in any way by private, corporate or even institutional (least of all foreign) interests, economic or otherwise. Their research is viewed as needing to be developed in dialogue with Mexican society so as to best promote openness and transparency in the pursuit of the common goals such as knowledge, sustainability and social justice. While within the biotechnological frame and its associated grouping of scientists, 'independence' refers to the right of scientists to carry out their tasks and to produce knowledge and techno-scientific findings within appropriately funded Mexican public laboratories and universities, in isolation of and disconnected from the uses and trajectories of such knowledge and technological creations outside the laboratory. For them, their responsibility is primarily scientific and intellectual, and their accountability is configured mostly in relation to the norms agreed within the scientific community as to what should guide good scientific research. Thus they tended to see their work as ending at the doors of their laboratories, where the social and political responsibilities associated with how GM crops are regulated and used in practice must begin.

Much of the rhetoric and many of the arguments underlying and fuelling the above distinct scientific discourses about GM crops and GM maize in Mexico were echoed by our research subjects in the context of their laboratory research. However, the participant observation and the interviews showed a deeper complexity and wider diversity of views, as well as a degree of ambivalence, particularly among the more junior (not necessarily younger) scientists, and specially with respect to GM maize. First, while the more senior researchers we interviewed were unequivocally in favour of GM crops and GM maize, it was more difficult for the junior researchers (from post-docs to master's students) to position themselves on the issue. Part of this reticence came from an ontological distinction many of them made between, on the one hand, genetic modification as a technological innovation in general, which they viewed as potentially a positive instrument for experimentation and knowledge generation; and, on the other hand, transgenesis, the introgression of exogenous genes from one species into another, which many considered 'unnatural' and more risky, particularly in relation to the maize genome. It is interesting to note how the ontological divide marked by them did not refer to their scientific technique of gene manipulation, which they characterised as a natural continuation of conventional approaches to agricultural seed selection and improvement. The rupture occurred at the 'unnatural' point of crossing species' barriers; this was most notable in the case of maize:

> We do not agree with transgenic genetic manipulation. Peasants have done [genetic manipulation] in an empirical manner for thousands of years, and here we do it more scientifically … The same cross-breeding [we do] can be done in a more natural way, but we just do it more directly and faster.
>
> *(Master's student)*

> We do not insert pieces of one jigsaw into another jigsaw. We use the natural tools which exist in maize's genome.
>
> *(Doctoral researcher)*

However, a few junior researchers declared themselves unambiguously pro-GMO, and argued that their scientific work, even in transgenesis, was no more than a continuation of nature's work in evolution. In the particular case of GM maize, reticence or ambivalence towards transgenesis could be attributed to the significant place of maize in Mexican society, economy and culture, which scientists, both junior and senior, recognised:

> [Maize] is our main food and the basis of many people's economy in many areas. We feel affection for [maize] because it is a food we have seen since we were kids, tamales, tortillas… We would die if we could not eat tortillas! It is very important for our identity; we are made of maize, as the story goes about the origins of the Mexican race.
>
> *(Academic technician)*

> Maize is a culturally important plant, and we hold it is such high esteem that nobody can touch neither maize nor the Virgin of Guadalupe! That is why people are so visceral [about GM maize]. It is as if it was sacred.
>
> *(Master's student)*

> Maize is my land, it is my mother, and it gives me the food that sustains me.
>
> *(Postdoctoral researcher)*

Moreover, the socio-cultural and economic importance of maize has permeated Mexican science to such an extent that scientists themselves recognised both the prestige and the opportunities attached to belonging to the 'scientific community of maize'. They recognised too the level of accountability and responsibility that is socially demanded when working with this plant:

> Research in maize is different, before I never had to respond to anyone in ethical terms, because [my research] did not generate that level of controversy. There is a difference between working with other plants and working with maize. I used to work with frijol [kidney bean] and nobody was interested, it hurts. But everyone is interested in maize, it is so strong. 'What are you going to do to the poor thing?' is what people ask me, and I tell them, 'the same as to the other plants, grow them and kill them'. I feel as if I was invading people's homes, going somewhere very sacred.
>
> *(Postdoctoral researcher)*

However, scientists' reticence about transgenic maize is not only ontologically or culturally informed. Junior researchers at Langebio also raised questions about the present limits of scientific knowledge with regards to GM maize, and expressed doubts about the possible impacts of GM maize on native maize biodiversity and on human health through direct consumption:

> GM crops could spell the end of maize's genetic diversity, because in cross-pollination they exchange genetic material and cross among them. Everyone knows that if you cultivate GM crop varieties in the field, they will mix with the landraces.
>
> *(Postdoctoral researcher)*

> We do not know how the transgene moves inside maize which could be a risk for both animals and humans who consume it.
>
> *(Master's student)*

Some junior researchers at the laboratory questioned whether there exists a real need to develop GM maize in the present Mexican agricultural context, and raised political economy questions regarding the motivations of seed companies, and the potential for benefits to poorer farmers and consumers:

> I can understand that maize can be made resistant to certain diseases or other damaging processes … but I do not agree with the [current] terms of [GM maize] commercialisation, that [seeds] would be the property of seed companies, that they could sell them at expensive prices, that they could

> harm smallholder farmers and consumers … That's why I am not comfortable with transgenic maize as a new product that companies want to use, because they are not concerned with real improvement, but only with economic benefits … Producers who cannot afford the technological packages that GM requires would be forced out of the market, and big agricultural monopolies would be created.
>
> *(Master's student)*

Due to the doubts expressed about the biosafety of transgenic maize, and about its potentially damaging socio-cultural and economic impacts on Mexican rural ways of life, some junior scientists were beginning to question their own role as genetic researchers and as potential future creators of transgenic forms of maize, and to re-evaluate their responsibilities towards different social groups and to Mexican society in general. However, they themselves recognised that an ethical examination of their scientific motivations, and of the consequences (even if unintended) of current practices, would not be an easy or even a possible thing to achieve, given the scarcity of resources, the absence of capacity training to think systematically about those issues and competing pressures of pursuing a scientific career:

> Technologies are the responsibility of both the designer and the user. The creator [of the technology] should be responsible, and thus be accountable for any consequences.
>
> *(Doctoral student)*

> There are funding and resource limitations, and we have to achieve things fast, and we [do not have time] to look at the consequences, the goal is to achieve, to arrive somewhere, and this makes things very reductionist. We do not have money to investigate consequences, it is a matter of being in a hurry and not having the resources.
>
> *(Postdoctoral researcher)*

> We rarely think about the consequences [of our work], we are not trained to think about that.
>
> *(Postdoctoral researcher)*

Those emergent ethical scruples were rarely shared by senior researchers, who promoted a more traditional idea about the boundaries of scientists' responsibilities:

> Science is neutral, and can be used to create equality or inequality. We do not all benefit in the same way, but this a social decision, a governmental decision, not the scientist's decision. If I worried about that, I would do nothing. Why would I bother to do agricultural studies? I know that those who are going to adopt [GM technology] are the largeholder, industrialised

> farmers, so what should I do? Then I better not do agriculture, or medicine, or electronics …
>
> *(Senior researcher and Head of Team)*

Finally, there was one feature which scientists at the laboratory shared with their fellow Mexican citizens: the scientists in our study also expressed mistrust in the government, and denounced corruption and a lack of democracy, transparency and participation at all levels:

> Here [in Mexico] there was no debate or appropriate regulation, because things are resolved just by taking the politicians out to dinner … Everything is very opaque. We do not believe in [democratic] mechanisms or anything of the kind, that's why we do not vote or participate anymore …
>
> *(Master's student)*

Focus groups with urban publics

Focus groups were conducted with urban publics in the city of Morelia, the capital of the State of Michoacán, in November and December 2012. Four separate focus groups took place, with people in the following categories:

- Young mothers aged 29–38, whose children went to the same local school.
- Professional women, aged 26–45, who worked in the academic environment of the National Autonomous University of Mexico (UNAM).
- Students at UNAM, all aged 25–30.
- People aged 22–39 who defined themselves as religious practitioners of different faiths (Catholic, Pentecostal, Christian and Maya).

A summary of the analysis of results of focus groups is presented below, and has been organised following relevant thematic headings.

All participants in the focus groups said they consumed maize products on a regular basis, ranging from the more traditional and local, such as *uchepos* (maize paste made from young corn and boiled inside a maize leaf), to the more modern, such as popcorn. Maize tortillas were consumed daily by all respondents, and although some of them bought industrially produced tortillas while others bought hand-made ones, everyone said they preferred tortillas made with criollo maize and in the traditional way, which they said they could distinguish by their look, consistency, colour, smell, taste and durability. Some maize foods were prepared and consumed on special occasions and were linked by participants to particular festivities and rituals and also to specific locations:

> Sometimes I cook tlacoyos [a thick oval blue maize tortilla filled with beans, cheese or potato], every time there is a festival. Last time I made them for the 15th of September [Mexican Independence Day] and everyone had to cook

> a typical food from their region, and I come from Tlaxcala, so I cooked tlacoyos.
>
> *(Doctoral student)*

Maize cookery was highly appreciated by participants, and associated not only as food and nutrition, but also as processes of emotional nourishment and care, and with the constitution and maintenance of relations and diverse social identities (gender, family, regional, national):

> When women are breastfeeding, they are given atole [white maize drink] so that they produce more milk.
>
> *(Communications graduate)*

> Tamales are very special in my family. We prepare them when the whole family is together, we make them to eat them together. We keep a few aside, and then we take those to work the following day, to your other social sphere, and you give them away to your colleagues.
>
> *(University lecturer)*

However, the maize food which elicited the richest responses from participants in terms of meaning and significance were the tortillas. Tortillas were identified with land and belonging, with the sense of being Mexican ('the base of our food', 'the maize from our land', 'a part of us'), with relations and affection ('home, love, pleasure') and with health and wellbeing. Criollo maize and its cooked products were also brought into conversations by participants to signify the memory of people's childhoods, which in many cases were spent either in the countryside or which included memories of relatives who cultivated maize, including grandparents. This clearly indicated the inter-generational proximity of rural and urban worlds in the Mexican imaginary and experience, and the connection with traditional agriculture and home grown native maize which transcended the 'symbolic' to enter the realm of the 'real' in the form of remembered meanings and values:

> [Tortillas] mean a great deal to me, because my maternal grandparents live in the countryside, and my grandmother was a farmer. I remember how, during my childhood, I would go to my granny's house at five in the morning to grind the *nixtamal* [boiled criollo maize] and she made the tortillas in an earthenware *comal* [flat plate used to cook the tortillas]. It was such a rural and rich way of making tortillas, they tasted like heaven … All my siblings and cousins waited beside the *comal* for my grandmother's tortillas. And that is how days started in the countryside. We also went to the milpa, and we helped my grandfather to thresh the cobs, and the stalks were used for the fire, and were also fed to the pigs. It brings me to a world that does not exist anymore: my grandparents are dead, and

> nobody carried on working their land, my uncles migrated, and my mum came to the city.
>
> *(Executive secretary)*

Most participants admitted they do not cook their own maize products anymore, due to the pressures and lack of time of urban living, and to the loss of know-how with respect to traditional maize cookery. However, they still bought maize foodstuffs, mostly from women known to them who cook in the traditional hand-made manner using native maize. It is interesting to note how our selected public participants choose these type of products not only because of the perceived sensorial qualities of the ingredients, but also because of the artisanal, careful manner in which they were made:

> The taste, the care … in hand-made tortillas, all the love from the woman who prepares them is embedded into the tortillas. I feel they are more nutritious than the industrial ones just because of this.
>
> *(Communications graduate)*

Most of the focus group participants stated that they did not have a clear understanding of what genetically modified organisms in general are and what transgenic corn in particular entails. Many said they had heard about the issue vaguely, but that it had been presented to them in a 'very abstract' manner, and in response, they asked for clear and unambiguous, neutral information. They tended to admit a lack of familiarity with the topic, to feel intimidated by the subject and to express an attitude of caution towards GM maize:

> I know [GMOs] are modifications which are made to the species in order to give it specific characteristics which are supposed to be better than the original. But perhaps if it is food which is genetically altered it is not necessarily good.
>
> *(Doctoral student in geophysics)*

Most respondents were unaware as to whether they were consuming GMOs or not, as they did not know which foods included them, due to the absence of GM labelling legislation in Mexico. While consumers expressed concern about the unknown dangers of GM foods and their long-term impact to human health and the environment, the lack of information made it difficult for them to make decisions, which caused frustration. They also questioned the science that is claiming that GM foods are safe. Like other stakeholders in the Mexican case study, our public participants distinguished GM foods from other applications of biotechnology (e.g. medicines). They did not doubt science's good intentions, but questioned its capacity to predict harm:

> Obviously, we believe that all [scientific] research has a good end, a charitable

> purpose. The intention is never to cause harm. But you cannot control all the variables. Experiments have apparently a good objective, but we really cannot know exactly what is going to happen.
>
> *(Physician)*

> When we talk about biotechnology, it is not bad. If I was told that a family member is sick and through biotechnology a cure can be found; of course, I'll say yes. When it comes to food I disagree; in terms of environmental and health risks, we do not know.
>
> *(Master's student)*

People also tended to situate their views on agricultural GMOs within broader political economy considerations. People expressed scepticism in the claimed benefits of GM crops and foods: questions were raised about whether there exists a genuine need for them, as many fundamentally mistrusted the intentions of seed companies and food multinationals, and the interests that appeared to underpin the motivation to promote and adopt GM crops in Mexico, particularly GM maize:

> I do not believe in Monsanto's social commitment, I do not believe they will bring a solution to the Mexican countryside.
>
> I believe that in this issue, as in many others, the political class is in collusion with the big corporations.
>
> I do not believe in Monsanto's declarations; its interests are only economic, they want to appropriate all seeds that mother earth naturally produces and in such a way to control all seed production and all consumption too, damaging those most in need, as usual.
>
> *(Anonymous writings on paper)*

Furthermore, associated with their general sense of uncertainty and suspicion, people expressed a feeling of impotence and negativity towards anticipated agricultural and food futures, as they saw few efficacious pathways to oppose governmental decisions, or to resist the dictates of a free market:

> I am fearful that the food shortage will become greater. There is fear of the unknown … that they are doing things that will harm or will cause problems, and we cannot stop them, and it is not in my power to tell the shop owner not to do such and such, or tell the company guy not to do such and such; it is not in my power.
>
> *(Administrative assistant)*

In summary, the words that most of the participants used to describe their feelings towards GM crops were: 'anger', 'sadness', 'worry', 'distrust', 'deception', 'abuse', 'indignation', 'confusion', 'suspicion', 'fear' and 'impotence'. These clearly related to their lack of trust in the good intentions of seed companies, in the government's ability (or will) to regulate GM crops and foods for the public's good and, to a lesser extent, in scientists' capacity to foresee and account for future safety problems with alimentary GMO's. People also used ontological arguments against GMOs and variably described GM crops as 'negative', 'artificial', 'unnatural', 'false' and 'manipulated' constructs.

Many of our participants perceived the debate on GM crops and foods and particularly on GM maize as 'closed', and as having been restricted only to 'experts', namely scientists and regulators. People generally did not feel that they had been included in the debate, and had little sense that their voices had been heard or taken into account. Nevertheless, they believed that they should be included in discussions about GM crops, together with smallholder farmers and citizens in general. Most of our public participants did have a positive image of traditional maize farmers ('they look after the environment') and called for an alliance between scientists, farmers and universities to open up the debate on GM maize, as they considered these actors and institutions to be the appropriate 'experts', rather than the politicians, who were perceived not to 'have the [necessary] knowledge' for decision-making. Our respondents suggested there were two types of scientists involved in the debate, those who are concerned about possible risks and who were involved with smallholder farmers and with society in general, and those who aligned themselves with power:

> [GM] Scientists use their discourse to sell; their arguments are for obtaining profit and money. Politicians want to sell to society the idea that GM crops will benefit us. Meanwhile, traditions, land, jobs and lives are being lost.
>
> *(Anonymous writings on paper)*

In discussions on decision-making process of GM regulation, participants tended to question the credibility of governmental regulatory bodies responsible for safeguarding food and health. They expressed concern as to whether regulations on GM crops were being properly implemented, as well as concern about the lack of public consultation, and whether it had been deliberately restricted and made opaque:

> There has just been no consultation … They appear in the newspapers, tiny and hidden, so nobody finds out, legally going through the motions. But most people are in obscurity.
>
> *(Doctoral student)*

Our respondents extended their mistrust and suspicion of calculated obscurity to food companies, who did not publish the transgenic origin of their products, protected by the absence of legislation regarding compulsory labelling in Mexico. Governmental data on GM crops and foods in general also tended to be mistrusted, due to their perceived proximity to corporate interests. A number of participants called for a federal system of GM food labelling, for more transparent and rigorous regulation and monitoring of GM foods, and for reliable information on risks and benefits of GM agriculture. Very little confidence was expressed in the capacity of the government, and of CIBIOGEM in particular, to handle these issues scrupulously, honestly and responsibly, not because of their technical inability, but because of the suspicion, and in some cases conviction, of the proximity and collusion between those Mexican public institutions and the interests of large food and seed multinationals.

> Transnational companies are the great powers behind the national governments. In formal terms, the executive and legislative bodies are the ones who define regulation and legislation, but there is a great deal of lobbying behind the scenes. It is in those lobbies, which happen in 'obscurity', where decisions are made about maintaining or giving preference to economic interests above social interests.
>
> *(Master's graduate in public policy)*

Deliberative workshop with stakeholders

The Mexican workshop took place in Mexico City at the National Autonomous University of Mexico (UNAM) campus over two days in April 2013. On the first day in the morning, members of the Mexican team presented preliminary results from the Mexican case study, followed by responses and a collective discussion, which then fed into to a deliberative activity and plenary session in the afternoon. Nearly 40 participants attended the first day's activities, drawn from a range of governmental, civic and private organisations representing academics and scientists, regulators, seed companies, social and religious activists, indigenous communities and smallholder farmers. Participants representing consumer associations and large- and medium-holder farmers had accepted the invitation but failed to attend. On the second day, a smaller number of participants held discussions from which a joint statement was composed, which was later published in the agricultural supplement of the reputed Mexican national newspaper *La Jornada* (Carro-Ripalda *et al.* 2013).

The workshop responses and discussions were dominated by a polarised debate between 'experts', that is, between different groups of scientists and academics employed by public and private institutions or working for non-governmental organisations. A section of the 'expert' participants (scientists in public institutions, seed companies' scientific representatives and technical regulators) argued that GM crops posed few risks, and defended the necessity to produce, implement and regulate GM maize in Mexico in order to respond to the need to increase crop production and to 'modernise' smallholder (traditional) Mexican agriculture, which at one point was referred to as 'backward'. Other public scientists and academics (biotechnologists, agronomists and social scientists), plus scientists collaborating with environmental NGOs insisted on the unknown risks posed by GM maize to human health and to the genetic integrity of native maize in its centre of origin, and also defended the right of smallholder farmers to their own forms of indigenous and traditional agriculture, which could be enhanced by alternative, non-GM varieties of improved maize. Those two positions represented two differing visions of maize (a commodity for the first group; an emblem and agent of Mexican national identity, sovereignty, tradition and indigeneity for the second) and of agriculture (a business in the first case, and the rightful practice of traditional cultures in the second). Those polarised perspectives reflected and condensed the crystallisation of pro-GM and anti-GM discourses in the public debate.

However, as the discussion progressed, some intermediate alternatives to unlock the debate were suggested by a few of the scientists and regulators, who wanted to move the issue from narrow technical aspects to a wider conversation about a national project for the future of agriculture:

> Agriculture in Mexico cannot be seen as a business, it has to be considered a matter of national security … It needs to be properly funded, producers will produce without the need to use GM crops. [GM] is undoubtedly a promising technology with a lot of potential, but at present it does not fulfil the conditions to respond to the world's food demands … Mexico should therefore close its borders and wait, protect its biodiversity, which is a demand from our ancestors and a duty to our future generations.
>
> *(Regulator and scientist)*

Non-GM maize alternatives were discussed for the improvement of agricultural production and smallholder farmers' lives, and everyone (except the seed representative) agreed that these would be preferable to GM maize, although there was also 'expert' debate about their actual effectiveness. Mexican scientific culture in general and the practices of some pro-GM scientists were criticised by a few of their anti-GM colleagues, who accused them of having 'sold out', that is, of putting their self-interested economic and career interests before those of society. Mexican scientific culture was condemned for lacking an integrated vision of its role in society, which was offered as an explanation about why while scientists' intentions were undoubtedly good, scientific products often lent themselves to manipulation by politics.

In the midst of this 'expert' and technical discussion, two voices appeared as both sidelined yet distinctly unique: those of smallholder farmers and of religious NGOs. Smallholder farmers took a few turns to speak, and their speeches reflected both their awareness of being excluded from the 'expert' debate ('I am a simple housewife, and I have no degrees … I cannot understand all the words which have been used') and the often untranslatable ontological specificity of their relationship with native maize and with maize agricultural practice (Carro-Ripalda and Astier 2014). Smallholder farmers spoke about how the impending implementation of GM maize might affect their livelihoods and those of their communities and complained that despite this direct effect of GM maize on their ways of life they had not been informed, consulted, or taken into account in research, implementation or policy-making decisions:

> We [smallholder farmers] have been utilised like objects, and not treated as subjects. I do not know how far my voice might reach now … and I am not very political, I simply do my job in the fields, for my family and my community … But I can see that [this debate] is like a fight, and we have not been taken into account, because there is plenty of talk about democracy, but nothing is really done democratically; and about this GM maize issue, once again, us peasants have been ignored. Over and over again the government tries to shut us up by giving us [handouts], but it is high time that we are taken into account.
>
> *(Smallholder farmer)*

Smallholder farmers posed some extremely relevant questions such as 'why do we need GM seeds if we know how to select and improve our own seed?', a question which addresses the issue of the real need for certain biotechnological products, of democratic and bottom up participation in agricultural technological development, of the hierarchy of different kinds of knowledge, and of the problem of agricultural de-skilling (Stone 2007). Unfortunately, none of the 'experts' answered this or any of the other questions asked by the smallholder producers.

Representatives of catholic and religious NGOs also opposed GM maize, but their rhetoric against this biotechnological product was firmly pivoted around social, cultural, economic and political arguments. They defended smallholder and indigenous farmers' rights to practice their own agriculture and to their own native seeds, not as a form of preservation of outdated 'traditions' but because these forms of maize agriculture were seen as environmentally sound, socio-culturally meaningful, and also economically sustainable for the rural poor in Mexico. They further denounced the lack of authentic democracy in the Mexican political system and the sensed duplicity of GM regulatory procedures, where there often appeared to exist a fiction of public and scientific consultations, and whose results were seen to rarely be taken into account, while politicians were deemed to be taking executive decisions about GM maize based purely on macro-economic considerations and on their own elitist interests.

During the deliberative session the participants, divided in three smaller groups, agreed that there were some common points among the 'expert' stakeholders, such as the need to reopen the GM maize debate by involving a wider section of the Mexican scientific community, but also discussed the difficulties of including other 'non-expert' groups and voices in the debate, such as those of smallholder farmers and consumers. They also talked about the need to expand the debate beyond scientific and technical considerations and to frame the discussions towards a national consensus on public policies for social development in Mexico, where all sorts of dimensions (cultural, economic, ethical, even spiritual) would be taken into account. When the groups reported their strategic priorities and action points in the plenary, they all agreed of the need to reopen the GM crop debate and to initiate a wide inclusive national conversation about social development and the future of agriculture. Two fundamental things were seen as needed. First, a system of appropriate, objective, disinterested information about GMOs designed specifically for rural and urban 'non-expert' publics, accompanied by a programme of inclusive consultations of all sectors, both of which would have a special focus on smallholder farmers. Second, and most important, an active moratorium should be put in place, a moratorium that would allow the continuation of scientific research and development in agricultural biotechnologies, while at the same time making it possible to hold conversations about both GM maize and about the place of GM crops in future agricultural and developmental plans for the country.

Conclusions

We now summarise the key findings from the Mexico case study. First, we reviewed the debate on GM maize in Mexico. We found that the controversy over GM maize came to prominence in 2001/2002, following a highly published article in the journal *Nature* reporting the flow of transgenes into wild maize populations (the paper was later retracted), setting the scene for subsequent widespread and continuous protest. Maize is highly culturally resonant in Mexico, and protests against GM maize came to signify the defence of Mexican culture and identity in the face of unwanted forms of imposed globalisation. We saw that decisions by regulatory bodies have been seen as compromised and lacking in transparency. They have been contested vocally by NGOs and questions have been raised about their legality. And there has been little sustained effort by institutional actors, including the Mexican state, to engage the public.

Second, we presented fieldwork research with mainly smallholder farmers and other stakeholders in the Pátzcuaro Lake region in the state of Michoacán. We found that debates on GM maize were situated within the context of an on-going crisis in rural agriculture. Within this context we found strong and enduring social relations around maize agriculture, reproduced by systems of local community exchange and day-to-day food and religious practices. Within this context GM maize was seen as a felt intrusion into traditional practices, with unknown and likely negative impacts. Suspicion was exacerbated by deep patterns of mistrust expressed in the motivations of key actors, including the government and the seed companies. Smallholder farmers were also ontologically opposed to GM maize, seeing it as artificial, unnecessary and a threat to traditional smallholder agriculture.

Third, we reported on the results of interviews with a variety of local stakeholders involved in the debate on GM crops. We found a clear division between the views of some of the respondents (smallholders, consumers, environmental NGOs, social scientists) and those of others (large producers and seed companies). For the former, traditional maize agriculture was perceived as highly significant for Mexican history and culture, GM maize was perceived as an imposition and transgression, and regulatory bodies and laws (including the Biosafety Law) were seen as compromised and ineffective. For the latter, GM maize was seen as part of a modernity that would transform the Mexican countryside from its current malaise.

Fourth, we reported on findings from a laboratory ethnography conducted at the National Laboratory of Genomics for Biodiversity (Langebio) in Guanajuato. We found a clear distinction within the laboratory, between senior and older researchers who were more avowedly in favour of the application of GM agricultural technologies tout court, including GM maize, and younger and more junior researchers who were more cautious and nuanced. For the latter, extreme care was advocated in any attempt to restructure the maize genome, with a strong preference not to use genetic material from other species, and to minimise any risk that could affect maize's integrity.

Fifth, we presented research with predominantly middle class urban publics on Mexican public responses to GM crops and foods. We found an appreciation of maize products and cooking as a part of Mexican identity and as a medium in the maintenance of diverse social practices. We identified a general negative reaction to GM foods and crops, especially to GM maize but to other GM crops too. This negative perception was compounded by various dynamics: by the sensed lack of unambiguous and reliable information, by the lack of labelling, by mistrust in the motives of those producing them, by the unknown dangers GM foods may bring and by the lack of proven necessity. The government, generally, was seen as in collusion with the large corporations at the expense of the public interest. Regulatory bodies were similarly lacking in credibility.

Sixth, we reported on a deliberative workshop, conducted with a range of national stakeholders, set up to explore research findings and how to develop the public debate on GM crops. With some exceptions (mainly some natural scientists and representatives of seed companies who believed that the argument in favour of GM agriculture had already been won) we found broad agreement on the need to open up the public debate. Particular calls were made to develop more rigorous policies on maize, to give more voice to smallholder farmers, to develop agricultural research that aims to secure genuine sustainable development and to reopen a debate on the production and conservation of native maize and food security.

We conclude by making a final observation concerning the development model that has tended to be associated with GM crops. At issue here is not simply a technology that involves the genetic modification of plants, but the model of development that this technology supports and fuels. In our research, some of the stakeholders saw promissory images and the defence of GM crops as a means of a particular kind of development that would bring increased productivity and yields, reduced usage of agrochemicals and carbon dioxide emissions, and a response to world hunger. However, for the majority of our stakeholders, GM agriculture was part of a different imaginary; in GM crops (in particular in the commercialisation of GM maize) they saw a technology that (perhaps unwittingly) would engender more land grabbing, more food insecurity, increased out-migration from the countryside, further social inequalities and the increase in the smallholder farmer's dependence on commercial monopolies.

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Notes

1 In Mexico, 75 per cent of farming units are classified as 'traditional' or 'subsistence'. Traditional farming produces a limited amount of surplus maize which can be sold at local markets; subsistence farming, on the other hand, seldom produces surplus maize, and often does not fulfil the nutritional needs of the family (Turrent Fernández and Serratos Hernández 2004).

2 In the particular case of maize, eight million hectares are planted with this crop every year; of these, 6.5 million hectares are rain-fed, a type of maize cultivation associated with smallholder farmers using traditional farming methods (Turrent Fernández *et al.* 2012: 7). In addition, communally owned land still represents over 50 per cent of the total acreage.

3 Hunger in this context is not interpreted as a lack of food, but as a lack of just distribution of resources (see Stone 2002).

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3

AN ANALYSIS OF THE GM CROP DEBATE IN BRAZIL

Julia S. Guivant and Phil Macnaghten

A review of the debate in Brazil

As noted in Chapter 1 of this volume, Brazil has experienced a very particular historical relationship with GM crops. Despite the controversy that has raged over the introduction of the technology since the 1990s internationally, Brazil's approval and application of GM crops since 2005 has been rapid, and in some ways remarkable. Indeed, even though GM crops were not legalised for cultivation until 2005, by 2013 Brazil had become the second largest producer of GM crops in the world, behind only the United States. In this chapter we start with an analysis of the factors that contributed to this rapid growth of application by farmers, while taking into account the manner in which various actors and coalitions have been resistant.

Our story starts in 1998 when the National Technical Committee on Biosafety (CTNBio), the Brazilian regulatory committee set up in 1995 as the key scientific and multilateral agency responsible for approvals, received its first application from the global biotechnology company Monsanto for approval of its Roundup Ready (RR) herbicide-tolerant GM soya. Even though CTNBio approved Monsanto's application, there remained dissonant voices both inside the committee and in and across different ministries, which diminished the authority of the decision (Bauer 2006). Indeed, a few days before the CTNBio decision, the Federal Court had upheld a case brought by Greenpeace and the consumer group Instituto Brasileiro de Defesa do Consumidor (IDEC), arguing that GM crops should undergo a local environmental impact assessment (EIA) prior to commercial application. Drawing on an interpretation of the precautionary principle in the 1988 Brazil constitution, the ruling required crop segregation, labelling and EIAs even for field trials, effectively establishing a judicial moratorium that continued until October 2003, when a presidential decree legalised GM crops on an annual basis until the Biosafety Law was ratified in April 2005.

The above judicial dynamics helped create a set of conditions in which GM crops came to occupy a place at the centre of a national debate. A political coalition began to consolidate against the widespread (yet illegal until 2005) adoption of GM crops, consisting of various NGOs, political parties, social movements, learned bodies and parts of the judiciary. Key members included: (parts of) the Workers Party (Partido dos Trabalhadores – PT), the Landless Workers Movement (Movimento dos Trabalhadores Sem Terra – MST), the Brazilian Society for the Progress of Science (SBPC), the Federal Prosecutor's Office, IDEC, Greenpeace, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), and state programmes of the Bureau of Consumer Protection (PROCON). This was a heterogeneous coalition that opened a political space for action against GM crops. The mix of social actors can be understood as a 'discourse coalition' (Hajer 1995), and included a coalition composed of scientists, politicians, activists and consumer organisations, who while sharing divergent interests, nevertheless adopted a common set of storylines, in this case against the widespread adoption of GM agricultural technologies. For example, one set of 'conventional' social actors, that included the PT and MST, incorporated the issue of GM crops within a leftist discourse against globalisation, imperialism, multinational corporations, the USA, the International Monetary Fund and so on (Guivant 2002). While another set of actors, that included Greenpeace, IDEC and federal public prosecutors, adopted a more internationally defined agenda, focusing on legal actions, with the objective of redefining CTNBio duties and decisions, while at the same time advocating food labelling and an active application of the precautionary principle (Guivant 2009).

The coalition in favour of GM adoption was composed of four main groups: scientists who sought to defend the authority and decisions of CTNBio, biotechnology company representatives (such as those of Monsanto), farmers associations, and, after 2002, some representatives and ministries of the Lula PT government. Key advocates included some prominent researchers, mainly from public universities and from Embrapa (Brazil's state-owned agricultural research organisation affiliated with the Ministry of Agriculture). Their argument tended to have an orthodox scientific and technocratic character, identifying the positions of the oppositional groups as unreasonable, uninformed, catastrophist and 'against progress'. A key claim was that opposition to GM crops was not based on the facts (or at least those facts derived from current risk science). The risk assessments of GMOs and their derivatives, according to this group, had established that there was no evidence of risk either in the production or in the consumption of GM crops and foods (Lajolo and Nutti 2003; Guivant *et al.* 2009a, 2009b).

Up until 2003, the coalition against GM crops retained its strength and profile, with high profile initiatives and campaigns, including in the media, in Congress and in international arenas. However, once Lula da Silva had begun his presidency in 2003, matters began to change direction. In March 2003, in response to strong pressure from Monsanto, farmers associations, scientists and politicians, and in the context of widespread smuggled GM seed being grown in the south of the country, President Lula issued two provisional executive orders,[1] in March and September 2003, that permitted the temporary sale and distribution of illegally grown GM soya and later the cultivation of GM seeds. This meant in effect the practical end of the moratorium on GM crops that had been in place since 1998. Later, in 2004, contestations and conflicts of interests surrounding the adoption of the proposed Biosafety Law took much of the attention of both coalitions. In the Senate, Marina Silva, at that time the Minister of Environment and a strong critic of GM crops (including the formal position of her government), and her allies, were comprehensively defeated when the Biosafety Law was approved in 2005. The Law determined that regulations and licenses for experimental crop commercialisation should be permitted so long as they complied with the principle of maximum precaution and the evaluation of national economic interests, food security and environmental impacts, as provided for in national legislation and in accordance with international agreements (see Pinto Vieira and Viera Jr 2005 for details of the Law). It also established labelling as mandatory.

Following the adoption of the Biosafety Law in 2005, and the subsequent raft of applications that were approved by CNTBio subsequent to its adoption, the coalition against GM crops began to lose momentum. The claims of international environmental organisations such as Greenpeace began to lose purchase, not least because their campaign had never effectively mobilised wider Brazilian society, or had engaged with the lived and material concerns of ordinary Brazilians (Guivant 2002, 2006; Hochstetler 2007; Hochstetler and Keck 2007). Indeed, attempts by the coalition to mobilise wider publics, or engage in broad public dialogue, have been analysed as relatively superficial attempts that reached mainly militants already engaged in the cause (Guivant 2009). Indeed, Greenpeace eventually withdrew its campaign against GM crops in Brazil in 2011, a function of its inability to mobilise opposition and debate following the approval of the Biosafety Law.

One of the main remaining actors from the coalition against GM crops is the NGO Family Agriculture and Agroecology (AS-PTA) that, since 1983, has sought to promote family farming and sustainable rural development in Brazil.[2] Following the approval of the Biosafety Law, AS-PTA argued (successfully) that the GMO-free Brazil campaign change its name to the Campaign for a Transgenic and Pesticide Free Ecological Brazil.[3] This attempt to merge two hitherto relatively unrelated issues can be seen as an innovative attempt to connect an issue on which there exists strong public concerns in Brazilian society (pesticide overuse) to the newer issue of GM crops and foods, in the hope that this association might be important for future mobilisation and in the construction of alternative notions of scientific citizenship (Callon *et al.* 2009; Macnaghten and Guivant 2011; Jasanoff 2011). AS-PTA actions include the rescue of native seed for smallholder family farmers (Santilli 2009) and critical positions against the process of approval of CTNBio, usually reported in their newsletter. Among AS-PTA allies, at least at the level of discourse, are the Nucleus of Agrarian Studies and Rural Development (NEAD), the National Council on Food and Nutrition Security (CONSEA) and some professional associations. NEAD, for example, part of the relatively recently created and family farm-oriented Ministry of Agrarian Development (MDA), has produced a number of booklets criticising the process of GMO approval (Ferment and Zanoni 2007; Zanoni and Ferment 2011).

CONSEA is another member of the new configuration of the alliance. It operates at the interface between government and civil society in the areas of food and nutrition. It has largely a consultancy character and advises the President of the Republic on the formulation of policies and rights. The president of CONSEA, Emilia Maria Pacheco, recently advocated the 'restoration' of the government's concern with genetically modified products. She said:

> We also have great concern with the expansion of the release of GMOs in the country, which is largely associated with increased pesticide consumption, as is the case of soya beans, and we advocate the application of the Precautionary Principle, on issues related to biotechnology.
>
> *(Pacheco 2012: 3)*

In addition, there is the National Nutrition Council (NCC), representing nutritionists, who have supported the coalition since around 2011. The NCC defends agro-ecology and family farming as a counter-weight to agribusiness and monoculture and as one of the conditions necessary for wholesome and nutritional food.

Since 2005, the coalition against GM crops has attempted to influence the approval decisions of CTNBio through the courts, with some success. In 2007, for example, members of the coalition filed a claim against the federal government contesting the decision of CTNBio to authorise the production, marketing and consumption of Bayer's Liberty Link Maize on the grounds that the conditions of coexistence and monitoring post-commercial release had not been met, as embodied in the Biosafety Law. The decision was upheld and CTNBio was obligated to impose stricter biosafety measures to ensure coexistence between organic, conventional and GM crop varieties. Nevertheless, despite some achievements that have helped to slow down or halt the decision-making process,[4] approvals of GM crops have continued at a considerable pace. As of 2013, approvals have been granted for 5 GM soya cultivars, 19 maize cultivars, 12 cotton cultivars and one black bean (*feijão*) cultivar. All the GM plants have been modified to be either herbicide tolerant or insect resistant or, in some recent cases, for both.

Since 2005, the rate of growth of GM crops in Brazil has been dramatic. According to the International Service for the Acquisition of Agri-biotech Applications (ISAAA 2013), an industry body funded by biotechnology companies including Monsanto, Bayer CropScience and CropLife International, the coverage of GM crops in Brazil had risen to 36.6 million hectares in 2012 or 21 per cent of the global biotechnology crop. This includes 23.9 million hectares devoted to GM soya bean, 12.1 million hectares to GM maize and 0.55 million hectares to GM cotton. Indeed, of the 44.7 million hectares devoted to these 3 crops across Brazil, 36.6 million hectares or 82 per cent were GM crops. Notwithstanding questions surrounding the reliability of these figures (for a critique of the methodology used by PG Economics in putting together such figures, see Food and Water Europe 2012; see also Dominic Glover's commentary in Chapter 8, this volume), such statistics nevertheless point to the rapid diffusion and adoption of GM crops.

Notwithstanding such growth, there are signs that we may be witnessing the beginnings of a new alliance promoting non-GM agriculture. In 2008 a new player emerged on the scene. The Brazilian Association of Non-Genetically Modified Grain Producers (Abrange), representing five of the most important soya bean companies (Grupo André Maggi, Caramuru, Imcopa, Vanguarda and Brejeiro), was set up as a consultative reference centre with a mission 'to institutionally promote [the] market for genetically modified free products, ensuring [that] consumers [are provided with] the right to choose', and 'to offer support to the agriculture business [and supply] chain with technological and innovative solutions, aiming at transparency, quality and safety [aligned] with economic, social, and environmental sustainability' (Abrange 2014). Following active discussion on the strategic need for Brazil to sustain its presence in non-GM markets (notably Europe), Embrapa aligned with Abrange and developed its own GM-free soya programme. There are important differences between this new coalition, centred on Abrange, and the previous coalition, centred on NGOs and social movements. While the old coalition campaigned against GM crops as a moral and political crusade, using arguments from bioethics, smallholder farmers' rights, native seeds and so on (Nelkin 1995: 451), the new coalition is more pragmatic, seeing its role as that of extending economic opportunities in the non-GM marketplace, more 'pro non-GMO' than 'anti-GMO'. Such an emergent storyline uses a different set of arguments emphasising the rhetoric of accountability, choice and the responsibility and rights of farmers. Nevertheless, on certain issues the 'new' and 'old' coalitions share a common voice, including growing concerns with weed resistance to glyphosate and their implications for increased herbicide use.

The field ethnography

The fieldwork ethnography in Brazil was conducted in the western region of the southern state of Santa Catarina between January and February 2013. The region was chosen as the research site because of the historical, social, economic and political relevance of its family farming traditions; the general pattern of income distribution and land occupation in the region, which is less concentrated than in other regions of the country; the fact that the region is one of the original sites of contemporary land reform and women farmers' movements in Brazil; the degree of heterogeneity of organisational forms in family farming economic activities (including collective production); and the growing adoption of GM soya bean and GM maize as the main crops in local farming practices. As with the other case studies, our research focused on ethnographic participation with smallholder family farmers and with representatives of NGOs, extension agencies and private companies (mainly seed industries, cooperatives and agro-industries) that provide

TABLE 3.1 GM crops in Brazil: chronology of events

Date	*Event*
1995	The regulatory committee CTNBio is set up to provide technical advice on requests for permission to release genetically modified organisms (GMOs).
1998	CTNBio receives its first application from the global biotechnology company Monsanto for approval of its Roundup Ready herbicide-tolerant GM soya. Even though this is approved by CTNBio, the Brazilian Federal Court upholds a case brought by Greenpeace and the consumer group Instituto Brasileiro de Defesa do Consumidor (IDEC), arguing that GM crops should undergo a local environmental impact assessment (EIA) prior to commercial application. This effectively establishes a judicial moratorium that continued until October 2003.
1999	A noisy confrontation takes place, and is sustained for the next five years between coalitions of actors arguing for and against the introduction of GM crops. The debate lacks widespread public engagement.
2003	Following widespread use of illegal GM soya in the southern states, President Lula issues a presidential decree that permits the temporary sale and distribution of illegally grown GM soya bean and later the use of the GM seeds on an annual basis.
2005	The Biosafety Law is approved. The Law determines that regulations and licenses for experimental crop commercialization commercialisation should be permitted so long as they comply with the principle of maximum precaution and the evaluation of national economic interests, food security and environmental impacts. It also establishes labelling as mandatory.
2005	Following the adoption of the law, the coalition against GM crops begins to lose momentum. The rate of growth of GM crops in Brazil increases exponentially, especially GM soya and GM maize. By 2012, the coverage of GM crops in Brazil had risen to 36.6 million hectares or 21 per cent of the global biotechnology crop. Brazil has become the world's second largest producer of GM crops, behind the United States.
2008	A new alliance develops promoting non-GM agriculture, centred on the Brazilian Association of Non-Genetically Modified Grain Producers (Abrange), acting in both GM and non-GM markets. Concerns with weed resistance to glyphosate begin to mount, with implications for increased herbicide use. The GMO-free campaign changes its name to the Campaign for a Transgenic and Pesticide Free Ecological Brazil.

technical assistance to farmers. We ran thirty-one interviews and undertook observation visits at agricultural product fairs (called 'Field Days'), ran by cooperatives in the region. In addition, we participated in meetings of trade unions and family farmers organisations.

In recent years, the western region of Santa Catarina has undergone a serious economic crisis exacerbated by falling relative prices of agricultural products, which is having a dramatic impact on rural communities. These problems began in the 1980s and intensified with a concentration of pig farming production, as pork

FIGURE 3.1 Map of fieldwork sites in Brazil

Source: http://d-maps.com/m/america/brazil/bresil/bresil42.gif

(and to a lesser extent poultry) agro-industries targeted only those producers who were able to increase both the scale of their operations and their productivity. Government agencies, the Catholic Church, the Lutheran Church and various NGOs – such as the Association of Western Santa Catarina Small Farmers (APACO)[5] and the Small Farmer Support Centre (CAPA),[6] sometimes working together with governmental agencies (such as the Ministry of the Environment or the Ministry of Agrarian Development) – have promoted the creation of associations as a way of combating the crisis of agriculture in the region and as providing alternative forms of production. The main option for family farming now lies in the production of GM soya, introduced in the region some 15 years ago. Over the last 5 years, GM maize has followed suit to become the second major local crop. The adoption of GM maize and soya is part of a broader set of transformations in local agricultural practices, which have facilitated the widespread diffusion of GM crops, reaching up to a 100 per cent adoption rate by large farms in the case of GM soya in the region, and around 30 per cent of all farms in the case of GM maize. Maize is an important component of the family farming model, connected to the production of milk and to its consumption by the farmers themselves and their families.

Everett Rogers wrote the classic text on diffusion studies in 1962, helping shape and bring into being an extensive scholarship on agricultural innovation, agricultural extension, knowledge transfer and local adaptation. However, research on the adoption of GM crops is less extensive with very little in-depth investigation of the social and cultural impacts of GM crops on small-scale, global South farmers. Indeed, current extant policy debates on GM crops tend to exclude the smallholder farmer's point of view. Either smallholder farmers are represented as the victim of outside corporate pressures (a rhetoric commonly promoted by NGO actors) or, alternatively, as having adopted the technology through rational market choices (a rhetoric commonly promoted by seed companies and government actors). Yet, to understand the rapid adoption of GM crops in Brazil, we need to pay attention to the social and institutional processes through which the technology was adapted, and the complex negotiation of meanings of GM crops as they became integrated into farming livelihoods (see Oudshoorn and Pinch 2005 for a general discussion on why users and non-users matter).

A typology of farming practices

In our ethnographic research we found a complex mosaic of combinations in the ways that GM crops had been adopted and diffused into farming practices in the region. The majority of smallholder farmers had adopted GM crop technologies and were farming different varieties of GM herbicide tolerant maize and soya beans. They had bought seeds through the main regional cooperatives and many of them were contracted by the big pork and poultry companies, such as Aurora and Seara. There are mainly two kinds of farming practice: one that involves the cultivation of GM crops (maize and soya) and one that does not. Within these two groupings are some distinctions.

Farmers cultivating non-GM crops

Farmers cultivating non-GM crops in our sample tended to be smallholder, organic or agro-ecological farmers who cultivated mainly horticulture, maize and beans and who raised dairy cows. These farmers had chosen not to adopt GM crops both because available funding for GM seeds was scarce and because they had chosen to grow what they considered to be high quality, healthy non-GM crop varieties both for their family and for particular niche markets. These farmers had adopted a rhetoric in which transgenic crops were avoided because they were associated with a form of high input, chemical-intensive agriculture that was seen as 'destroying' and 'polluting nature'. These farmers tended to demonstrate significant concerns about unhealthy eating practices, about pesticide residues in food and about the overuse of agrochemicals in agriculture. Within this group of farmers were two clusters:

- Farmers cultivating non-GM organic soya and other organic horticulture products including creole maize – this cluster was composed of smallholder organic farmers who cultivated creole maize seeds, many of which had been distributed free of cost through regional, state assisted small-scale cooperatives. In addition, Epagri (the rural extension agency of Santa Catarina state government) had provided 'improved' creole seed varieties that had been bred to be more resilient to pests and resistant to droughts than traditional varieties. However, in our research we found that farmers worried that these seeds were not a good long-term option for a variety of reasons: because their preferential offer had been reduced and because they were not perceived to be as resistant to climate variation as GM seeds. It can be predicted that these seeds will continue to lose market share in the face of the continued predominance of GM seeds. For some farmers, creole maize was used to feed dairy cows especially for personal consumption where farmers were concerned that GM maize could 'contaminate' their cows' milk, given the perception of outstanding uncertainties on grounds of safety and perceptions of improved taste.
- Farmers cultivating non-GM creole maize and conventional soya seeds – this cluster of farmers had abandoned organic production for reasons that included the adventitious presence of GM crops (and associated problems of pest control) from neighbouring farms. GM crops were seen to be responsible for the spreading of pests to their crops, which had proved to be very difficult to control, thus endangering coexistence. These farmers claimed that neighbouring farms had not respected the segregation distances required by law and that herbicides had been spread by neighbours onto their farms using tractors – for some 'in total disregard'. These farmers were critical of GM crops and associated farming practices, and tended to emphasise the environmental and health problems the latter may cause. The land was seen as already 'intoxicated' and as needing to be 'detoxed', just as one would with regards to one's health.

Farmers cultivating GM crops

Farmers cultivating GM crops in our sample were small and medium-scale farmers, who had followed the trends facilitated by the most important regional cooperatives (like Cooperalfa). These were capitalized farms that exhibited a significant infrastructure for production and that were open to what was considered as 'progressive' and 'modern' technological innovations.

- Farmers cultivating GM soya and creole maize seeds – a number of these farmers had previously been swine and poultry producers involved in contract farming. First, they had changed to dairy milk production and later to GM soya bean cultivation. They tended to display a well-organised administration and were market oriented. Many continued to cultivate creole maize, especially for local family consumption, because they found the taste of the maize sweeter and the content richer in proteins than GM varieties. The function of GM soya bean cultivation was to sell to the cooperatives. For them, the main advantage of GM soya was that it is easy to plant and that it reduced costs, principally because pesticides needed to be applied only once. With the conventional seed, they need to clean the '*inço*' (weeds), and apply pesticides many times.

- Farmers cultivating GM seeds only – again, for these farmers the main advantage of GM soya and maize was the ways in which GM crop technologies had simplified working practices. With conventional crops, farmers had needed to be much more precise about the amount of agro-chemicals used and when to apply them. GM crops, as one of them described, are 'beautiful, grow quickly and are clean'. However, even these producers tended to avoid direct consumption of GM food products, reserving some of their subsistence farming for the use of conventional or creole seeds, particularly maize. Practically all of animals used in meat production were fed GM soya and maize.

Factors mediating concerns over GM soya and maize

Gender

Gender was a factor mediating farmers' perceptions of GM crops, derived from a clear division of labour that continues to endure around agricultural practices in the region. We found that women largely produce vegetables and fruit for family consumption and take care of animals (pigs, cows, and chicken) whereas men are involved in decision-making and in working on grain crops. Choices on seed purchasing, sowing, handling and other related issues are typically made by men. We found that the women who were most active in the production process tended to be those involved in organic production or in the cultivation of creole maize. In our research, these women spoke enthusiastically about their values and about their engagement in wider activities outside the farm (for example, the women farmers' movement). One example was a woman farmer from a farm that centred on milk production and the cultivation of creole maize. She was part of a women's group of farmers that produced and exchanged seeds of different vegetables, including a type of lettuce (*rabicho*), among others. They met once a month and exchanged information and seeds. These women were also involved with the cultivation and exchange of medicinal herbs, something very valuable in the region, given that these are used both for human health and well-being as well as for animal husbandry. These women also played a critical role in the handling and preservation of creole seeds. Although some of these women did not seem to worry about eating GM maize, most associated healthy food consumption with non-GM (and preferably organic) products. For the group of women who worked with GM crops, grain crops tended to be represented as 'men's issues'. Some women farmers even found it hard to provide specific information on arable crops in their farms, for example on areas under cultivation, or on the types of seed used. The women tended to be in charge of growing vegetables and fruit, mainly for family consumption, and in activities related to the care of animals (cows, pigs, chicken). These women appeared to be marginalised from decision-making processes on arable production, and thus from the question of whether or not to adopt GM crops.

Food practices

We found that the food practices of farming communities had changed significantly in the last few decades. Some food recipes used in the preparation of meals were still traditional but the ingredients used were increasingly bought at local supermarkets. For example, in the preparation of traditional *polenta* with maize, farmers now tended to buy the flour from supermarkets, whereas when these female farmers spoke about how it had been when they were children, everything then had been produced at the farm. Nevertheless, some farmers still produced creole maize using a traditional windmill in their locality to make flour, which they would then keep frozen for consumption all year round. Mainly organic farmers were careful about sustaining this tradition not least because they wanted to make sure that the ingredients they were consuming had not been 'contaminated' by pesticides. For the farmers cultivating creole and conventional maize, the former was preferred for family consumption not least because the taste was perceived to be sweeter.

Farmer–expert conflicts

In a number of interviews with stakeholders in the region, we identified tensions between farmers who had adopted GM seeds and technicians from seed companies, as to the cause of the problem of weed resistance that was being witnessed increasingly with GM crop production. Both farmers and representatives of major seed companies operating in the region (Pioneer, Monsanto, etc.) both recognised the problem and tended to blame each other for it. The increasing resistance of some weeds to glyphosate herbicide used on GM soya is already widespread in crops across the three southern Brazilian states (Rio Grande do Sul, Santa Catarina and Parana). In infected crops, the fall in productivity can reach 40 per cent, not counting the costs associated with the need for increased herbicide use and the loss of quality of soya bean due to higher grain moisture and impurity. In our research, we found that technicians from the seed companies complained that farmers were not following recommendations: for example about maintaining a buffer zone between GM and non-GM crops, or doing crop rotation. Not adopting such precautionary measures was for the seed company representatives the source of increased weed resistance. For them, farmers were to blame:

> Farmers do not follow the technical recommendations. They do not keep the buffer zone, [they] fail to do crop rotation, and apply more glyphosate than they should. Overdosing is a major problem. All this is bringing many problems to farmers as they are losing their yields … so we put a lot of emphasis on [good] management.
>
> *(Monsanto Roundup Ready technician)*

From the technical experts' point of view these 'bad' practices were seen as having been triggered by farmers' desire for 'short-term' profit:

> They [farmers] see profit; they only want profit. Soya bean prices are good, so they see no need to rotate [soya] with another product; but they are going against themselves because [subsequent] weed management is complicated and expensive.
>
> *(Monsanto Roundup Ready technician)*

Farmers who already were facing the problem of weed resistance, however, claimed that they were not the ones responsible for this situation and that the problem of weed resistance had arisen because the technology had not fulfilled its claimed promises. However, these farmers hoped and believed that 'science' would find new alternatives:

> Will there be a day when things [referring to herbicide tolerant weeds] will be put right? [Yes] Because science tries to evolve. I believe, I hope, that with more research things will work better for us. We depend on it [science] for our health, and for the wellbeing of animals and farming. We depend on researchers and those who are in search of new knowledge.'
>
> *(Farmer)*

Interestingly, in our research we found that representatives of small cooperatives tended to side with the farmers, blaming the technicians of the seed industries (and not the farmer) for the problem of weed resistance:

> What we observed was that farmers had planted GM crops without following any of the recommendations, without even knowing the law. The law requires the use of buffer zones. Yet, farmers are tricked by technicians from seed companies who say that GM crops are cheaper, that they yield more – which is a lie, because they do not produce more. If you take a variety of Pioneer GM seed and another non-GM variety, they yield just about the same.'
>
> *(Farming cooperative representative)*

This understanding of the conflict, as explained in terms of the different attribution of blame by actors, points to the active role of users in shaping their relationship with technology, and in this case to key differences in the use and adoption of GM crops by farmers compared to those assumptions designed into the technology by innovators. Indeed, one has to ask whether the problem of weed resistance is a product of unrealistic assumptions being built into the design of the technology system? The discipline of science and technology studies (STS) has a long tradition of research that has examined the relationship between design preconceptions in innovation architectures and the future uses of those systems in practice (Bijker and Law 1992; Winner 1986). Akrich and Latour (1992: 226) use the concept of an 'anti-programme' to describe user actions that do not align with designer's scripts about what ought to take place. They further offer the term 'de-inscription' to describe the period of adjustment that needs to take place between idealised use (or those uses assumed to take place by designers) and actual use in everyday practices in the real world. In our research we saw that this 'de-inscription' has yet to take place. With little recognition by representatives of the seed companies of the everyday lived realities of farmers, and thus of the implausibility of prescriptions and recommendations being operationalised into agricultural practices, it is difficult to see how this conflict will be resolved or settled in the near future. Whether farmers continue to buy the promises and apparent 'hype' of the seed companies in the medium term future remains an open question.

To summarise, we found that those farmers who had not adopted GM crops had found themselves pushed to the margins of the productive system, and to have needed support for sustained non-GM crop cultivation from small regional cooperatives, NGOs and local markets. Many of these farmers had become involved in the production of organic horticulture and in the sowing of creole seeds of maize, both for animal feed for domestic production and for direct consumption. There were a number of important perceived advantages in the adoption of GM seed from the point of view of farmers: less demand for manual work (relevant in the context of the growing rural exodus of the youngest), more free time, and better productivity and prices. Although there was some degree of coexistence of GM seeds with creole and hybrid varieties, we found that coexistence practices were often not harmonious, and that alternatives to GM agriculture were being increasingly narrowed. The scale of adoption of GM seeds, and the compounded impact of the considerable 'rural exodus' of farmers and younger generations towards urban areas, alongside pressures coming from cooperatives and larger producers, have led to a situation in which few questions were being raised about GM crop technologies. GM crops had tended to be accepted on pragmatic terms, whether as survival for smallholder farmers, as market rationale for cooperatives, large agribusiness companies and governments, or as competitive innovation for scientists and technicians.

However, it is far from clear whether the perceived advantages of GM crops will be sustained in the long-term, especially in relation to the promises and claims of benefit from the seed companies. Indeed, one can suggest that there exists at present a degree of hype in relation to GM crops, defined as an 'overestimation of the significance of a new discovery, invention, or application of science and a focus more on the benefits and less in the risks' (Master and Resnik 2013: 324). So far, the acceptance of GM crops, and their embedding in everyday farming practices, have been sustained by a widespread belief that GM crop technologies will continue to simplify agricultural production and that they will continue to improve farmers' livelihoods. Indeed, this belief is dependent on the assumption that if difficulties emerge downstream – and are happening in relation to the increasingly persistent problem of so-called 'superweeds' (i.e. weeds resistant to the herbicide that is part of the GM technology package) – that these problems will be overcome through further scientific innovation and advance, involving typically more advanced GM crop technologies. Whether this belief will be sustained in the future remains again an open question.

Interviews with stakeholders

Using a list of open questions we undertook a series of face-to-face interviews in the west of Santa Catarina, with representatives from a public research centre, a social movement organisation, a NGO and with technicians from seed companies. We also undertook an electronic survey, identical to what was used in the other national project case studies, which we sent to over two hundred people in the region, with a 12.5 per cent return rate. The majority of the respondents were highly educated, holding either a PhD or a master's degree. About two-thirds of the respondents were male. Nearly all of the respondents considered themselves 'well' or 'reasonably informed' about debates on agricultural biotechnology. Yet a clear minority of those sampled expressed positive opinions on how open or how accessible the debate of GM crops and foods in Brazil had been, up until now.

We found that representatives from NGOs and from social movements deployed an anti-GM discourse, using predominantly principled arguments in their opposition to GM crops. In interviews with scientists and with technicians from seed companies, in contrast, the debate tended to be framed around the opposition between 'modern' (GM) and 'backward' (non-GM) agricultural practices. But virtually all stakeholders were well aware of one dynamic: the increased operation of major multinational agricultural corporations in the region (such as Pioneer, Monsanto and Dow), heavily impacting on the local economy and on local farming practices. Indeed, notwithstanding the views of some hard-core scientists, there was often some sensitivity from actors that GM crops, and the more intensive agricultural systems of which they are part, posed potential negative and long-term impacts on traditional forms of life and local cultures. It was also clear that despite the widespread uptake of GM crops, many stakeholders felt that a host of relevant issues have not been tackled, that a good deal of relevant information has not been presented and discussed, and that some relevant stakeholders have been either unnecessarily neglected or disregarded in the process. Many also raised questions about the lack of participation in technical decisions and the apparent disregard of social actors affected by them.

Opinion on GM crops

In the questionnaire responses, there were conflicting views on respondents' general opinions on GM crops. When forced to choose only three responses (out of 13 options) a significant number of respondents aligned their opinion with negative claims. A significant number of respondents agreed that GM agriculture 'creates dependency on seed industries' (48 per cent), that GM agriculture 'may cause problems to the environment and/or to human health' (45 per cent), that 'GM agriculture actually worsens conditions in rural areas' (31 per cent), that GM agriculture 'destroys local cultures and traditions'[7] (31 per cent) and that 'GM crops are definitively harmful to human health and the environment' (17 per cent). Responding to positive claims of GM agriculture, a number of respondents agreed that GM agriculture constitutes a 'beneficial scientific advance' (38 per cent), that GM agriculture 'helps towards feeding the world' (21 per cent), that GM agriculture helps Brazil to become 'economically competitive and to enter global markets (14 per cent) and that GM crops provides 'benefits for the economic development of the country' (14 per cent). Thus, to summarise, the three consistent negative views associated with GM agriculture were 'dependency', 'possible threats to the environment and human health' and 'threats to traditional forms of life', while the three positive claims were 'scientific progress', 'global food security' and 'economic competitiveness'.

Openness and efficacy of the public debate on GM

Although the large majority of respondents (around 70 per cent) agreed with the claim that the debate has all but receded, respondents were at the same time of the view that access to quality information by the general public had been limited (80 per cent). Respondents also tended to agree with the claim that the technology had made little in-roads into solving current problems on agricultural innovation and food security (45 per cent). One reason may refer precisely to the lack of opportunity for widespread participation, as indicated above, which was viewed by respondents as having been dominated by the presence of a few powerful voices. Indeed, when assessing (on a range of 0–5) how 'loudly' relevant voices have been heard, large farmers, scientists, businesspeople scored at least 3.4, whereas smallholder farmers, consumers, women, indigenous and religious groups never scored higher than 1.4. Politicians and NGOs were perceived at an intermediary level, at an average of 3 and 3.3 respectively. Such figures changed slightly when it came to their views on who had real power to effect decisions and norms: politicians, businesspeople and large farmers stand out, in this order, as the most effective actors, though people also knew that formal decisions are taken mostly within technical committees with only marginal formal representation from non-academics. Indeed, whereas people view scientists as their main source of authority of these issues (over 55 per cent choose scientists as an authoritative source, or an average 4.3 out of 5), decisions were seen as not solely guided by science, since corporations and large producers were also seen to have influence, thus demonstrating a particular social and political bias. Down the scale, indigenous groups, religious groups, women's groups and consumer organisations featured lowest in having the least perceived power to influence decisions. While business-people and large farmers were by far those who were seen to benefit most from GM agriculture, indigenous people, religious groups and women were seen as those who would be the most disadvantaged. Smallholder farmers still clearly lose out, consistently scoring around 1.3 on average.

Who participates? Who decides?

Various open-ended responses to questions on participation and decision-making processes point to a tension between whether the debate on GM agriculture should be framed by expert and scientific knowledge or whether social dimensions and ethical considerations should also be considered. Although both dimensions were highly valued, they tend to differentiate as one approaches issues of evaluation and implementation. Responding to an open question on who should take part in decision-making processes, the majority of respondents promoted the idea of independent, science-based technical committees. However, respondents differed on the latter's composition: whether these should be composed of natural scientists alone or whether this should include in addition a blend of social scientists, representatives of civil society without political attachments, and social actors affected by the technology. As seen above, this former position points to a certain view of science as apolitical, neutral, and therefore of scientists as critical actors in decision-making processes. What the second position adds is a qualification for such blanket legitimacy: scientists must consult with other social and economic sectors and 'filter' their positions in order to reach a robust and fair conclusion. A related point concerns who should *not* be involved in decision-making processes. A number of respondents suggested that all those who are directly identified with, or who represent political or economic interests, should be excluded, whether these be social movement actors (seen as tendentiously radical), seed industry representatives or scientists working for the seed companies. A few replies focused on social actors who were seen as having inadequate knowledge to be involved, including indigenous groups, who were rarely seen as having a special stake in the issue.[8] A similar logic applies to religious groups, who were thought not to be relevant or to be an appropriate voice to be taken on board in the discussion of GM issues.[9] When asked about which actors should have additional influence in the decision-making process, besides scientists, there was a significant stress on the role of consumers.

Ethnography at a research laboratory

The laboratory ethnography was undertaken at the soya research division of the Brazilian Agricultural Research Company (Embrapa), located in Londrina, in the southern state of Paraná.[10] The research took place on two separate occasions: the first, involving the application of a questionnaire and some secondary data collection on the operation of the unit, followed by a 20-day period of direct on-site ethnographic observation. Embrapa is a state-owned agricultural research organisation set up by the Brazilian government in 1972, organised as a distributed network composed of 47 relatively autonomous decentralised centres, spread across several regions and working across six Brazilian biomes (Amazon, Cerrado, Atlantic Forest, Caatinga, Pantanal and Pampa). It employs a 2,389-strong research team (about 25 per cent of its workforce). It is a public company affiliated to the Ministry of Agriculture, Livestock and Supply (MAPA). The National Centre for Soya Research – Embrapa Soja (CNPSO) was set up in 1975 and was responsible for the early expansion and adaptation of soya in Brazil, undertaking pioneering work to enable the soya bean to be adapted to the hot, humid and acid climes of the Cerrado biome, helping to position the country among the world leaders in soya productivity. Described as a 'world reference centre for the cultivation of soya bean in the tropics', it is situated on an 864-acre experimental farm housing 29 labs, 34 greenhouses, support installations and administrative areas, in which nearly 230 people work, 63 of whom are researchers. The centre's research agenda is shaped by national strategies for the sector. In partnership with companies and private foundations the centre runs 105 experimental areas distributed by different biomes. Their research agenda is determined by institutional criteria (such as Embrapa's strategic plan), international agreements, market demands, projects proposed by researchers themselves, and especially the national development strategies for the agricultural sector.

Following the approval of GM crops in 2005, CNPSO scientists divided into two groups: the majority were in favour of the immediate release of GM crops whereas a smaller group of scientists defended the adoption of the precautionary principle. This latter position partially overlapped with the one held by the broader coalition opposed to the release of GM crops. However, the arguments promoted by Embrapa scientists tended to focus on questions of national sovereignty: for them it was critical to develop a strong national science base to make it competitive, to undertake their own GM crop research and to avoid technological dependence on outside foreign corporations. In 2001, the Biosafety of Transgenic Products project was set up in order to adapt Embrapa to international demands, to establish new partnerships, and to have access to funding sources to facilitate the marketing and licensing of GM products.

Interviews with scientists working for CNPSO indicated that they viewed GM crop technology as providing clear potential both to improve food quality, to further Brazil's economic interests and to help feed a growing global population. For them, GM crops were seen as critical to further the national priorities of developing countries. However, in contrast with Embrapa's major achievements in the past, in recent years the organisation had lost ground to multinational biotechnology companies who had led the way in developing new varieties of GM soya and maize for Brazil's large agricultural sector. Field research data revealed that, between 2005 and 2008, the company controlled about 75 per cent of soya bean cultivars in Brazil; by 2013, that figure had dropped to only 7–8 per cent. Embrapa scientists attributed this decline in market share to a combination of factors that included chronic underfunding and a cumbersome bureaucracy.

Embrapa researchers did not see any major difference in kind between GM and conventional soya beans. The key aspect in GM crop technology, they suggested, lay in its ability to modify characteristics or traits, introducing or modifying genes for plants or animals to produce targeted results. Every species is susceptible to improvements, in principle, and in this case Embrapa researchers saw their role as that of producing more productive and resilient cultivars, including those with added genetic resistance to pests and major diseases. GM crop technology tended to be viewed as equivalent to other kinds of agricultural innovation but with added potential. For these researchers, the possibilities for future development were seen as enormous, and researchers evaluated that the varieties that have been released today are safe, in that modern science had found no evidence that the risks of harm to the environment or to human health to be significant. Moreover, if risks were to be identified in the future, Embrapa researchers believed that these could be adequately controlled on a case-by-case basis within current frameworks of regulation and oversight:

> There is no great difference between regular and transgenic soya beans. Differences are quite particular. Is there a difference? There is a difference! Soya beans are different among themselves. You have thousands of soya bean cultivars, each different from the others. If you collect wild soya beans all are different. It's the same variability among humans, no two people are alike.
>
> *(Embrapa researcher)*

Scientists acknowledged that even within the scientific community there is still debate about how much is known about GMOs, both in terms of understanding basic genetic processes and their potential for the genetic improvement of plants. This situation was seen as positive given that it opens up apparently limitless possibilities for research (and subsequent application). Genetic modification was seen as allowing for the indefinite extension of human intervention in nature. Researchers also stressed that the use of new technologies should not be at the expense of previous ones. Generally, it was seen as necessary to use technologies in an integrated and combined manner. The exclusive use of a specific technology can lead to imbalances and, in extreme cases, can lessen the production potential of the agricultural system. If farmers, for example, in order to maximise short-term profits and minimise labour, did not undertake proper management in their adoption of GM crops, in a few years plants and insects would become resistant, as was seen to be happening with weeds that have acquired resistance to glyphosate. Thus, while farmers were seen as important players in the adoption of new technologies, they are also seen as chiefly responsible for the shortcomings of GM crop technologies. The ability of Brazilian science to develop innovative new agricultural technologies was one of the points highlighted by researchers. However, they warned that, although Brazilian science has a proud tradition, the current model of Embrapa's state-funded research – its level of funding, and its associated business model – have restricted its research work and its ability to develop genuinely transformative technologies for widespread adoption in Brazilian agriculture.

When considering the role of the wider public, Embrapa researchers had a tendency to reproduce the same kinds of arguments that are available on the official website of CNPSO. The arguments were simple and tended to be based on instrumental reasoning. The CNPSO researchers emphasised the economic benefits of GM crops, the benefits of GM seeds such as those that offered resistance to diseases, as well as the potential for GM crops to lock in improvements in nutritional compounds. All the above were seen as promising benefits to the consumer. The researchers did not offer much in the way of explanation for the endurance of scientific controversies on GMOs or on the potential risks associated with scientific breakthroughs. They were however convinced not only that the technology can deliver on productivity and safe consumption, but that a ban on GM crops would incur a much slower development of conventional alternatives, leading to overall decreased productivity and higher prices. Legal and funding constraints on the development of research and partnerships were seen also to reproduce external technological dependency, which did not help poorer (or scientifically more peripheral) countries or research communities, including Embrapa itself. When questioned if human beings have the right to modify the natural structure of the soya genome, researchers tended to invoke arguments of national sovereignty, the necessity of scientific advance and the challenge of world hunger. For them the genetic code is universal; if something works well on a plant, when transferred to another it will/ should also work. Why not use this knowledge and procedure? As one researcher stated, 'if you understand that the genetic code is universal, you cut and paste [genetic information] from one species to another – that will work [too]'. Thus, in principle, everything is amenable to be manipulated, provided it is done, according to them, in an 'ethical and rational way'. In that respect, researchers were not willing to endorse any and every kind of possible GM plant intervention, but called for case-by-case discrimination. Embrapa researchers admitted that farmers or society at large had not requested GM crop technology, and that seed companies had offered the technology to farmers in a top-down manner. However, it was argued, if the technology had not been helpful to farmers it would not have been adopted by so many. Currently, one interviewee noted, a farmer who does not use the technology is left out of 90 per cent of the market.

There was little evidence of a structured and sustained debate with society at large. Lay opinion tended to be dismissed as ill-informed and as overly focused on the negative aspects of the technology. Any existing dialogue with those outside the laboratory had to date been restricted largely to farmers and academic peers. Even in the latter case, human and social scientists who are members of CTNBio, for instance, were often mistrusted in their scientific credentials. Embrapa scientists did not feel they needed 'to sell' their achievements by convincing the wider public. Rather, according to these scientists, it is up to the market and for individual consumers to decide whether or not to adopt GM crops and eat GM food products. For the researchers interviewed, Embrapa's target stakeholder was the farmer, not the consumer. For these reasons we found that there was no clear and deliberate strategy for Embrapa to communicate to a wider audience of relevant interlocutors, nor was there a developed or collective sense of accountability to the general public who will be affected by the technology, even in the absence of whether the public had intentionally chosen or not to eat GM foods.[11]

This understanding also leads to the complicated question as to what constitutes the relevant role and rationale for the human and social sciences. For the latter, criteria of informed, meaningful and fair participation are often viewed as a necessary pre-condition for the legitimacy of public decisions, technical and scientific ones included. Given that this understanding is not shared by for example Embrapa researchers, it is thus not surprising that dialogue across the natural and social sciences remains fraught with misconceptions and resistances. Respondents did agree, however, that a debate with society is not a practice of the laboratory, and considered this a communication failure, even though a number of them considered the regulatory committee CTNBio to be a more appropriate forum for such a debate. Overall, the voices of non-scientists were seen as unqualified for this task both for failing to understand what GMOs are and for introducing unscientific considerations into the debate (for instance, through 'ideological' premises). According to our respondents, although GMOs are widely discussed they are poorly understood. For our researchers, debates arising from society were seen as guided by political actors who do not know the benefits of the technology and who, in general, emphasise only the negative aspects. Interestingly, this argument does not apply to private sector seed companies or farmers who seek economic gain out of the technology, and who engage in partnerships with scientists to fund research and its outputs.

Focus groups with lay publics

As observed in Chapter 1 of this volume, we know very little about what ordinary publics think about GM crops and foods, including in Brazil.[12] We know little about whether people are generally for or against the technology. We know little about how people think about the technology. We know little about how public opinion is structured across age, gender and social class. And we do not know what social factors are important in structuring public responses. Brazil presents an interesting case given the strategic importance of (GM) agriculture to the Brazilian economy and due to the fact that Brazilian publics have been eating GM foods now for over a decade. Indeed, in the absence of a sustained research effort, more or less all that we know about public attitudes is that most people appear to know very little about GM technologies and their application in crops and foods. This is perhaps not surprising given that there has not existed a sustained effort by institutional actors – government ministries, funding agencies, regulatory bodies, seed companies, NGOs or the media – to inform public on GM foods and crops or to enter into dialogue on the issues associated.

Our research on Brazilian publics was conducted to help fill this gap. The research involved the design, conduct and interpretation of five in-depth focus group discussions, which took place in Florianopolis in the state of Santa Catarina between November 2012 and February 2013. Our research methodology was designed to elicit clues about factors shaping public attitudes, in a field where few people could be said to be knowledgeable about the technology and its application, or who could be claimed to have 'settled' or 'informed' views. The focus group discussions reflected a spectrum of social classes and age groups, with a particular bias towards women and the middle classes. Each group included five to eight participants and lasted up to two and a half hours. The sampling specification was theoretically derived: designed to cover a diverse variety of background but with topic-specific variants. The first two groups were of professional men and women (all class A or B), chosen because of their relatively high levels of education and personal agency, and their likely engagement with complex issues of governance and decision-making processes. The third group was of housewives and mothers of young children (all class B), chosen because of their status as mothers and their likely detailed engagement with food and culinary processes. The fourth group was one of men and women with strong religious beliefs, from a diverse range of classes and levels of education, chosen to explore the religious dimensions to public responses on GM foods. The fifth group, in turn, was composed of students, all studying social sciences at the Federal University of Santa Catarina, chosen to explore the views of young people.

The materials were developed by the authors and presented using a data projector. Aligned to the focus group discussions conducted in the other national case studies, the groups began with a discussion of food, designed to understand how people understood and used foods in daily life, how food was embedded in everyday practices, why they made the food choices they did and the role of health, naturalness, tradition and different sources of information in these choices. This was followed by a discussion on the concept of GM foods and crops: what they are, the history of their production and use in Brazilian agriculture, their diffusion into different kinds of food products, the existence of labelling schemes and their potential for GM technologies to create new kinds of foods. Subsequently, current debates on GM crops and foods were set out and discussed, both those in favour of the technology and its widespread application and those against. While in the fourth and final part of the discussion participants explored the responsibilities and roles of different actors in the debate, including their own.

We found that food was a topic of growing salience for Brazilians. In all the group discussions, with the partial exception of the students' group, there was a lively and articulate discussion of food and food practices and of their increasing importance in everyday life. For some participants there was an appreciation of the lifecycle of foods, and of the social and ecological processes involved as foodstuffs travel from the field to the plate. Especially for women, good food was seen as a core contributor to health and well-being. There was a fairly intense concern with the industrialisation of foods, and, for at least the better off, a desire to consume foods as organic and local as possible as a response. There was also a consciousness about the factors contributing to unhealthy foods: about the use of pesticides and herbicides, and the overuse of salt, sugar and unsaturated fats. However, such concerns tended to be considered at the level of individual health rather than as a wider concern with the environment, and were viscerally expressed at certain life stages, such as when women had become mothers of young children. Participants, for the most part, displayed an intense desire for reliable and trustworthy information on nutritional content and more broadly on healthy foods. However, while people tended to trust expert systems, including science, they rarely trusted the media to provide such information – which was seen as typically producing inconsistent, contradictory advice, all too often aligned with their own 'self-interests' – preferring instead to rely on face-to-face contact with nutritionists and other trusted individuals.

When introduced to the concept of genetic modification, and the subsequent and widespread adoption of the technology both in Brazilian agriculture and across an extensive array of everyday food products, participants expressed surprise. Few were knowledgeable about GM agricultural technologies and fewer still were aware of the extent to which the technology had become permeated into everyday food products. Across all the groups, people responded negatively and for two reasons: because of the outstanding scientific uncertainties surrounding the health impacts of GM foods, and because they had not been consulted and clearly informed. These two factors led to an array of visceral responses: 'I feel betrayed'; 'we are all guinea pigs'; 'even with our level of enlightenment, we ignored it'; '[this] is a leap in the dark'.

As the groups developed their thinking on GM crops and foods throughout the discussions their attitudes became more settled and mature. Broadly speaking, participants saw few direct benefits from GM agriculture for consumers. GM crops had not in their day-to-day experience reduced the cost of foods (at that time rising food prices was a national concern); they had not apparently produced environmental benefits (a number of participants were aware of the expanding use of synthetic pesticides in Brazilian agriculture, including the use of products banned in other countries); they had produced few apparent health benefits (only unknown long-term risks); they were viewed as benefitting the large producer at the expense of the traditional family farmer; they were seen as providing foodstuffs principally for animal feed and thus as having had little practical impact in feeding the poor; and they were perceived as being regulated by interests which were not purely scientific thus questioning the impartial and public authority of science (an institution that tends still to be trusted in Brazil). And in addition, when asked to reflect on the label that is currently used in (some) food packaging to denote the use of GMOs – a small T sign set in black against a yellow triangular background with the associated text that it had contains transgenic material – people for the most part claimed that the label was both confusing and misleading. Here is how the group of students responded (names have been anonymised):

NICO: Here you see 'tested and approved': it's all hype! And that goes for everything we consume, since more and more will be produced [with GMOs]. I think the move is great for entrepreneurs who want to produce more. Not caring if they harm or kill or if many people die from cancer or diseases … Are [they] not concerned with that? [No] only with production and earning profit.

GISELA: I think it will not end world hunger. It is another advertisement, as mentioned above.

ELISA: It's moving everything into the hands of science and … 'we buy'. We purchase a medicine or food that is ready in 15 minutes. There is a whole chain of factors that are needed to combat hunger. It is not simply GM [crops] that will fight hunger …

NICO: What is missing for sure is information. In my family there are three nutritionists; so I guess I should have known [about GMOs]. Someone told me something and that has given me a warning. As a dietician who works with this [food] in a clinical capacity, I see that people have a number of concerns with GM foods and that there is no help. I do not think they [nutritionists] know about this. *(Students)*

For the participants, the key point of disagreement within the groups was not whether GM agriculture was a good or a bad thing (most of the participants were fairly negative in this regard), but of the relative importance of GM foods as an issue as it compared with more immediate social, political and cultural issues in Brazil (including food issues such as obesity and the over-use of salt and sugar in Brazilian diets).

We next presented participants with some of the key debates and arguments on GM crops and foods, both for and against. On the one hand, arguments were examined concerning their claims in providing solutions to world hunger and global food security, their role in contributing to national economic competitiveness and their potential to stimulate scientific innovation. While on the other hand claims were examined concerning outstanding risks to the environment and human health, religious arguments against messing with God's creation, as well as problems of injustice and the concentration of economic power in the hands of the few. Participants tended to respond in a couple of ways. On the one hand the materials confirmed to them that the public debate had so far been largely restricted to academic scientists, government actors and seed companies at the expense of wider civil society, with the additional sense that these actors may have 'manipulated' the debate to promote their own interests. Thus, a number of participants were highly motivated to uncover those elements which (to them) appeared to have been kept invisible, such as the need for wider discussion and research on the possible (long-term) risks of GM foods. In relation to arguments in favour of GMOs, there was some salience in the argument that GM foods could help feed the world, although most participants suggested that the problem was political and cultural in character, involving more than simply the production and allocation of increasing quantities of foodstuffs to the poor. Surprisingly, participants omitted any reflections on the importance of Brazil's competitiveness in strategic sectors, whether in technological innovation or in food production, even though a number of participants held professions that were in some way related to commerce.

We then explored how people perceived key actors involved in the debate on GM crops including government, regulators, large and smallholder agricultural producers, NGOs and the academy. Contrary to expectations, NGOs were repeatedly mentioned as actors not to be trusted, not least because of recent high profile cases of corruption. Scientists with links to the seed industries were also discredited. This kind of scientist was seen to be committed to the promotion of economic interests rather than the public interest, and thereby questionable in terms of his or her scientific credentials. The seed companies similarly were not trusted given that their interest lay in promoting commerce, not the public interest. Indeed, the same dynamic held for the media, who again were seen as inevitably compromised through their need to promote their own self-interests. Responsibility, by contrast, was seen to lie primarily with government and with educational establishments, notably public universities. Participants called for government to be held to be responsible for regulation, for safety assurance, for consciousness raising and for the promotion of the public interest. Interestingly, few people considered that the government had fulfilled these obligations so far in a credible manner. Participants called for scientists to be responsible for the conduct of research in the public interest, and for universities – and to a lesser extent schools – for be responsible for fostering critical and participative citizens through education.[13] The responsibility of NGOs, participants suggested, should be to bring information into the public realm. Below is how the group of male professionals discussed the role of universities:

FEDERICO: Who is going to be part of this debate on [GMOs]? In this respect, I think we need better training for our consumers. The education system has a responsibility to develop our capacity to discuss controversial issues. Without saying what is good or bad, because I think it is not for us to judge, and the school cannot provide all the answers – I think science cannot [provide all the answers] – but at least it can promote discussion …

RAFAEL: … what I meant by that is that education exists not at the university level, but at a more basic level – but we have little investment in education. And we know that in Brazil, the majority of the population receives public education. Now this is the issue, this government's disinterest in investing in basic education to produce a critical citizen – that is just one more bullshit, it [education currently] is more to keep kids in school while parents work, just to reach the end, and they all leave school unquestioningly.

(Professional men)

Deliberative workshop with stakeholders

The final element of the research was a Brazilian workshop organised with national stakeholders on the theme of GM crops and which was held in Florianopolis in Santa Catarina.[14] The workshop was divided into a series of presentations of preliminary results of the field research, followed by plenary discussion, followed by a deliberative session with participants. The presentations included short talks on the ethnographic field research with smallholder farmers, the ethnographic laboratory research with CNPSO (Embrapa Soja), and the focus group research with urban publics. The deliberative session was divided into small group work followed by a plenary presentation of each group's conclusions followed by plenary discussion. The workshop generally aimed to foster reflection and informal group deliberation on the research preliminary outcomes and to explore whether and how to 'open up' the debate on GM crops within current considerations of 'political economy'.

Participants were drawn from a range of governmental, civic and private organisations representing scientists, traders, social activists and smallholder farmers. The following organisations were represented:

- The Brazilian Agricultural Research Corporation (Embrapa);
- Serra Geral Hillsides Ecological Farmers Association (AGRECO);
- Council for Information on Biotechnology (CIB);
- Federation of Workers in Family Agriculture in the state of Santa Catarina (FETRAF);
- Centre for Support to Small Farmers (CAPA);
- National Technical Committee on Biosafety (CTNBio);
- Ministry of the Environment (MMA);
- Ministry of Agriculture, Livestock and Supply (MAPA);
- Agricultural and Livestock Farming Research and Rural Extension Company (EPAGRI);
- Brazilian Association of Farmers of Non-Genetically Modified Crops (ABRANGE); and
- the National Council of Food Security (CONSEA).

Though basically considered as an issue that has been 'settled' by scientists, seed companies and government officials, GM crops and foods were seen as poorly and ambivalently understood in the absence of an informed public debate. Fieldwork results and the workshop's discussions were seen as revealing large gaps in public knowledge, disputed evidence as to the benefits of GM crops, and distinct social impacts arising from its pattern of adoption by smallholder farmers, women and consumers. With few exceptions, the majority of participants agreed on the need to reopen a public debate on GM crops and foods: on its regulation and oversight, on the need for concerted action to communicate reliable information, and for proper channels of citizen participation in strategic decision-making. Though the priorities and suggested actions were not directly equivalent across the three groups, as could be expected, there were interesting overlaps. Group 1 prioritised a demand for central government to undertake a mediating role in the debate, and to take responsibility to clarify issues on GM foods to the wider population. Its preferred actions involved communication (through devising strategies to reach different publics) and education (stressing the provision of reliable information on GM crops and foods and their various effects on food production and public health). Group 2 prioritised the promotion of citizens' participation in GM crop and food debates. The suggested actions were to organise deliberative policy conferences (a participatory tool that has had significant impact in Brazil since the 1990s) on GM agriculture, to promote related mobilisations such as at agricultural fairs, to campaign for GM-free zones and to make activist use of social media. Group 3 prioritised educational activities, through the use of public events and the internet. In summary, educational activities were targeted as a way forward, with particular roles allocated for governments and for organised civil society. The state was seen as a major nodal point in the various recommendations, being asked to mediate, to promote informed debate and to provide participatory channels for public deliberation.

Despite a few disagreements during the discussions, some of which were sharp (particularly between scientists, farmers and anti-GM activists), the choice of priorities was developed without significant glitches. An underlying acknowledgement was that even though ordinary lay Brazilians had not shown explicit interest in the GM crop and food question, communication and education was needed to raise the public salience of the issue. This proposed action was seen as supported by the urban publics in the focus groups who while generally unknowledgeable on this issue, nevertheless called for rigorous and unbiased information on GM crops and foods, on where it was being adopted and why, and on the various issues (both positive and negative) associated with its adoption. It was also argued that media dissemination alone was not enough, because of how the media was seen as likely to contribute to fragmented and disputed views, thus potentially contributing to further public uncertainty and confusion. In any case, there were acknowledged to be different ideological positions that needed to be accurately reflected both in the media and in the academy. For this reason, informed debate and educational strategies were seen as necessary. Education was associated with the right to be properly informed and as a necessary precondition for a genuine public debate, thus closely connected to questions of participation. Teachers, university lecturers, researchers and journalists, accordingly, were seen as key actors, alongside consumer and citizen groups, to promote better access to clear and reliable information and data on policy options.

Conclusions

The key findings from the Brazil case study are now summarised. First, we reviewed the debate on GM crops in Brazil. We identified the trajectory of the debate and the factors that led both to the resistance and to the widespread adoption and take-up of GM crops in Brazil, analysing the actors, discourses, arguments, politics and governmental and legal actions. We found that the story of GM crops in Brazil had been deeply polemical, plural (at the level of elite actors if not of wider society) and political. We concluded the section by pointing to the changing structure of the non-GMO alliance – more pro non-GM than anti-GM – and its potential for future mobilisation in the context of growing concerns over weed resistance to glyphosate and their implications for increased herbicide and pesticide use.

Second, we presented fieldwork research with family farmers, women's groups and representatives from seed companies from the western agricultural part of the southern state of Santa Catarina. We identified the various ways in which GM crop technologies had been adopted into local agricultural practices. While GM crops were perceived to have certain technical advantages (e.g. ease of working the land), we found that GM crops had tended to be accepted mainly on pragmatic terms, whether as survival for smallholder farmers, as market rationale for cooperatives and producers, or as competitive innovation for scientists and technicians. Especially women and those working in organic agriculture felt marginalised from debates on GM crops, which in many cases were impacting on their livelihoods but which tended to be presented as an inevitable part of Brazil's agricultural future. We also found evidence of a conflict between farmers and technical experts from the seed companies, each blaming each other for the growing problem of weed resistance to glyphosate.

Third, we reported on the results of a survey and interview research with a variety of local stakeholders involved in the debate on GM agriculture. Notwithstanding a diversity of views, we found a clear alignment of responses with negative claims, chiefly: the propensity of GM agriculture to create dependency on seed companies, to cause potential problems with human health and/or the environment, and to threaten traditional forms of life. We found that while most respondents agreed that the debate had receded, that it had been thus far dominated by a few powerful voices (large farmers, scientists and corporate interests), and that there had been limited involvement of the wider public or access to quality information.

Fourth, we reported on findings from a laboratory ethnography conducted at the soya research division (CNPSO) of the state-owned agricultural research organisation Embrapa, located in the southern state of Paraná. We found clear and unqualified optimism among scientists on the role of GM crop technologies to provide significant future agricultural improvement, and to produce more productive and resilient cultivars with genetic resistance to pests and major diseases. The arguments deployed tended to be instrumental and nationalistic, emphasising economic benefits, the apparent unparalleled ability of GM crop technologies to provide 'improvements' and the necessity for agricultural GM research to have a strong national base. We also found little evidence of a structured and sustained debate with wider society who was represented, by and large, as uninformed. Non-scientific actors were seen as equally unqualified for entering the debate on GM crops.

Fifth, we presented research with urban publics on Brazilian responses to GM crops and foods. Using a series of focus group discussions, we found evidence of food quality and safety as a topic of growing salience for urban Brazilians, with a fairly intense concern with the industrialisation of foods, and, for at least the better off, a desire to consume foods as organic and local as possible as a response. When introduced to the topic of GM crops and foods, we found little knowledge or awareness and genuine surprise about the extent of its adoption. Notwithstanding a general trust in expert systems, including science, participants adopted largely negative opinions to GM crops and foods in the discussions, not least because the technology was seen as benefiting the producer (not the consumer) and because they had not been consulted or clearly informed. They were concerned that the public debate had so far been largely restricted to academic scientists, government actors and seed companies at the expense of wider civil society, with the additional sense that these actors may have 'manipulated' the debate to promote their own interests. As a response, participants called for wider responsibility, particularly from government, for assuring more robust regulation and oversight, for raising consciousness and for promoting the public interest.

Sixth, we reported on a deliberative workshop, conducted with a range of national stakeholders, set up to explore research findings and how to develop the public debate on GM crops. We found that the clear majority of participants agreed on the need to reopen the debate on GM crops, on its regulation and oversight, on the need for concerted action to communicate reliable information, and for proper channels of citizen participation in strategic decisions. We found also a widespread feeling of impotence in confronting the power of the current alliance between scientists, the seed companies and politicians.

There are two points to make on the implications of the findings for governance: first, that public debates are rarely settled once and for all, especially when in the past these have been restricted to a limited number of organised actors; second, that in democratic societies there is a growing expectation that experts and scientists have a responsibility towards society, beyond the mere provision of reliable knowledge. These points together imply that the institutional staging of two-way public debates on GM crops are a critical element in producing socially robust and fair decisions, and that public institutions have a responsibility to secure effective participation, involving a broad range of stakeholders in decision-making processes. The Brazilian case study on the adoption of GM crops represents a highly technocratic approach to science-based public policy-making. The GM case is thus one in a long tradition of top-down, closed-circuit policy-making, which continues despite changes to the structure and culture of the Brazilian state, and to expectations of transparency, accountability and inclusive participation as promoted by organised civil society. More deliberative forms of policy-making seem to be a particularly relevant condition for the development of socially sensitive public policy.

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Notes

1 Provisional executive orders (*medidas provisórias*) are issued directly by the president and have immediate effect, but must go through parliament's vote within sixty days (extendable for the same duration) or lose legal force. They are meant to provide the government with effective decision-making powers but must be grounded on two criteria: urgency and relevance.

2 Stemming from a Project on 'technological alternatives' launched by FASE, one of the oldest Brazilian NGOs, AS-PTA, like so many other Brazilian civil society groups, has its roots in Catholic Church pastoral initiatives and organisational forms (cf. Riffell 2002).

3 Another channel and expression of the anti-GM coalition is the Ecovida Agroecology Network, set up in 1998 to promote agroecological practices within family farming nationwide. It is originally grounded in, and has been sustained by, church-related NGOs and grassroots organisations (see Rover 2011; De Souza 2011).

4 A recent initiative by the Federal Public Prosecutors' Office (Ministério Público Federal) in October 2013 was to ask the National Technical Commission on Biosafety (CTNBio) to suspend deliberations on the release of transgenic crops resistant to pesticides 'until public hearings are held and conclusive studies on the impacts on the environment and human health have been carried out' (see IDEC 2013).

5 One of the most active NGOs in the region, APACO, was set up in 1989 with support from the rural labour movement and the Catholic Church, and is aimed at providing both technical and financial assistance to farmers' groups (see www.apaco.org.br).

6 CAPA was set up in 1979 by the Evangelical Church of Lutheran Confession in Brazil (IECLB), the main Lutheran strand in the country, and provides technical and financial support to small farming agroecology in the southern states of Rio Grande do Sul, (west of) Santa Catarina and Paraná (see www.capa.org.br).

7 This rises to 52 per cent when projected towards the future of agriculture and of the country in general.

8 The apparent indifferent attitude towards indigenous peoples among respondents should not, we suggest, be taken at face value, given that there exists in various regions of western Santa Catarina state a historical struggle to reclaim ancestral land, with some degree of success.

9 This again contrasts with the role that some religious organisations – especially Catholic and Lutheran – have adopted, providing grassroots support to small farmers, landless workers and indigenous communities in the region.

10 We are very grateful to Adilson Alves, who conducted the lab ethnography and who wrote the initial analysis.

11 It is important to stress that these views do not express the position of Embrapa as an organisation, including the strategic vision of the company as a whole, but rather the views of the interviewed researchers who observed these dynamics from the lab bench.

12 We are very grateful to Naira Tomeillo, who co-led the focus group research and who contributed to the initial analysis.

13 A very similar position was expressed by participants in the deliberative workshop, who tended to expect the university (and somehow schools as well) to play such a role.

14 We are very grateful to Joanildo Burity for his help in conducting the deliberative workshop and for contributing to this analysis.

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4

AN ANALYSIS OF THE GM CROP DEBATE IN INDIA

Yulia Egorova, Rajeswari S. Raina and Kamminthang Mantuong

A review of the debate in India

The debate in India on GM crops draws on a complex mix of agrarian, environmental, legal and development discourses, woven together by pro- and anti-GM actors within a wider set of narratives on modernisation, globalisation and nationalism. Before we enter the arena of agricultural GM debates, we provide a brief introduction to locate the debate in the challenges faced by contemporary Indian agriculture. A key and ongoing political challenge in India is how to feed a population of 1.1 billion (and growing). Given that this population will bring with it the demographic dividend of a young workforce, the demand for food as a condition for sustained industrial growth is a key driver of India's macro-economic policies. According to global development data collected by the World Bank, unlike Brazil and Mexico, where agriculture accounted for 11 per cent and 9 per cent of the national GDP in 1980, and 6 per cent and 4 per cent in 2010, the figures in India were 36 per cent in 1980 and 19 per cent in 2010. If this presents a hopeful sign of sequential development, as countries progress from agrarian to industrial economies, the problem of structural unemployment in India denies that hope. With the share of the rural population in the country at just over 70 per cent of the total population in 2010 (compared with 14 per cent in Brazil and 22 per cent in Mexico), India's population remains predominantly agrarian and rural, constituting in 2011 around 55 per cent of the total workforce, or a total of 263 million farmers and labourers. Of these 85 per cent are marginal or smallholder farmers (i.e. they cultivate less than 2 hectares of land) who farm 44 per cent of the total acreage under cultivation (Ministry of Home Affairs 2011; DoAC 2011). Indian agriculture is indeed the 'last bastion' of the peasant farmer (Hobsbawm 2007).

India is one of 17 megadiverse countries, as defined by the environmental organisation Conversation International, and home to four of the largest biodiversity hotspots in the global South. This biodiversity of thousands of cultivated, wild relatives and non-cultivated species, nurtured by millions of smallholder farmers, commons and forests, is seen as part of the solution for agriculture and food security, as well as a key global economic and cultural heritage (UNCTAD 2013). With the jury still out on whether the Green Revolution was a blessing or curse – in the light of rapidly reported falls in the growth rate of food production and productivity from monocrop irrigated chemical intensive cereal production systems, negative impacts on natural resources, persistent hunger and malnutrition, and major disconnects between agriculture, nutrition and the environment (among many others, see Deaton and Dreze 2009; Gillespie *et al.* 2012; ICAR 1998; IFPRI 2002; von Grebmer *et al.* 2013) – the reality checklist of how to connect GM crops to the contemporary challenges of Indian agriculture is being used rhetorically both by pro- and anti-GM campaigners.

The arguments given both for promoting and resisting the introduction of GM crops often stem from evaluations derived from the above checklist. For their promoters, GM crops are claimed to provide significant potential benefits for India that include: increasing agricultural production and productivity, trade gains, safeguarding food security, enhancing the nutritional quality of cereals, introducing stress tolerant crops, achieving better pest control through disease resistant and herbicide tolerant crops, improving rural conditions, meeting demand from farmers and advancing knowledge (see Borlaug 2007; Herring 2007; James 2008, 2010; Indira *et al.* 2005; Qaim and Kouser 2013). For their opponents, by contrast, GM crops raise significant concerns for Indian agriculture that include: toxicity in the food system, contamination of wild relatives of cultivated species, reduction in choice and in farmer's control over seeds, and phenotypic variations in the build-up and expression of GM traits (toxins or stress tolerance) in the target crop. In addition GM crops are seen as having contributed to associated crop loss, escalating input prices, access constraints faced by millions of smallholder farmers, the appropriation of benefits by the global seed and chemical industry, the emergence of pesticide resistant weeds and insects, and the destruction of the rich biodiversity and local knowledge base of marginal and smallholder farmers (ASHA 2013; Chaturvedi 2002; Das 2006; Kranthi *et al.* 2005; Lipton 2007; Ramanjaneyulu and Kuruganti 2006; Rawat *et al.* 2011; Shiva 1997, 2006; Stone 2007, 2011). There is also concern expressed about the food security rhetoric that has been deployed by pro-GM actors, including how this has over-simplified and at times misrepresented the dynamics of corporate and political power in shaping agricultural policy and practice (Newell and Glover 2003; Glover 2010a, 2010b; Menon and Siddharthan 2011; Scoones 2006; Stone and Glover 2011). As we will see later in this review section, although currently no GM food is produced in India, the public debate in India about GM remains one of the most lively in the world. The attempts to introduce GM *Bt* brinjal (aubergine), in particular, reveals the role of different actors involved in agricultural biotechnology in India and the complex relationships that exist between public policy, science and technology innovation, agriculture and the environment.

The actors in the debate

India's GM story begins with the New Policy on Seed Development of 1988, aimed at stimulating the growth of private seed companies; a linked US$150 million loan from the World Bank to India's seed sector, aimed at making it more 'market responsive'; and the 1989 Rules of the Environmental Protection Act (1986) which established the Genetic Engineering Approval Committee (GEAC) as the inter-ministerial body ultimately responsible for the approval of GM crops. India's seed industry emerged as a key strategic actor in the 1990s, amidst policy concerns over the TRIPS agreement and the introduction of intellectual property rights (IPR) in biological material (genes, varieties, and processes of genetic manipulation) in the early 1990s (Seshia 2002; Shiva 1997; Scoones 2006). The 1990s witnessed the increased importation and sale of commercial seeds as well as increased investment by private (domestic and multinational) industry in the seed sector. The seed industry focused on the development, sale and distribution of high value hybrid crops: chiefly of cereals, vegetables and fibre, and cotton. By 2009, commercial hybrid seeds were sown in almost 90 per cent of the acreage under bajra (Pearl Millet) cultivation, 95 per cent of the acreage under sunflower cultivation and 80 per cent under cotton cultivation (Sangar *et al.* 2012).

National media focus on GM crops began in 1993 with civil society actors and environmentalists articulating fears of proprietary control over plant material that had previously been selected, bred and nurtured by farmers over centuries (Shiva 1997). This concern was heightened in 1998 with fears that Monsanto's importation of genetically modified *Bt* cotton into India would include a terminator gene that would in effect make farmers dependent on buying seed from seed companies on a ongoing basis. Despite Monsanto's protestations that this would not be the case, the campaign led by NGOs touched many chords and *Bt* cotton became symbolic of a struggle against multinationals, neoliberal logics, the US, and India's economic liberalisation and globalisation policies. The KRRS (Karnataka Rajya Raitha Sangha or the Karnataka State Farmers Association) became highly active in mobilising an NGO-led campaign 'Monsanto leaves India'. Its leader, Professor Nanjundaswamy, created a set of slogans ('Stop Genetic Engineering', 'No Patents on Life', 'Cremate Monsanto', 'Bury the WTO') and gave notice that all trial sites would be burnt. The media debate continued at a high pitch throughout 1999 and 2000.

Much of the above anti-GM activity went counter to what the Indian government perceived as necessary for the modernisation of agriculture; indeed, by the 1990s agricultural biotechnology research and innovation was receiving significant support from the state. As discussed above, some of the key institutional support structures required for GM crops had already been put in place by the Indian government in the late 1980s and 1990s, starting with the New Seed Policy and the IPR regime. Coming in the wake of plateauing yield growth rates and the end of the first phase of the Green Revolution (ICAR 1998), agricultural biotechnology and GM crops in particular were welcomed by the government

(Swaminathan 2004). In addition, at this time, India's highly centralised public sector agricultural research was facing its own legitimacy crisis with declining incremental yield response to chemical inputs, increasing environmental costs of conventional chemical intensive crop production and failing extension activities (Raina 2011). International competition, the desire not to be 'overtaken' by China in advanced science and technology, and the need to promote India as a leading advanced scientific and innovation-oriented nation were further drivers that led to substantial investment by the public sector in the development of GM crops: rice in particular (Indira *et al.* 2005).

Public sector research on GM crops began in India in the early 1990s with active support and funding from the Department of Biotechnology (DBT) (*ibid.*). Although some scientists opined that in India there is sufficient scope for breeding high yield variety (HYV) seeds through conventional plant breeding methods using indigenous varieties (Mehta 2013), most scientists were key actors supporting the cause of GM crops. Out of 19 GM crops that have been developed in 24 publicly funded institutions in India, GM rice is the most intensively researched crop, with 15 institutions working on varieties aimed at increasing resistance to insects and other viral and fungal diseases, varieties bred for increased tolerance to drought and salinity, varieties with delayed ripening aimed at improving shelf life, and varieties with improved protein and micronutrient contents (Indira *et al.* 2005). With the exception of the 'Amaranthus' gene (used for protein addition), developed and isolated by an Indian research team from New Delhi, all other transgenes used in GM crop research in India have originated from abroad, either from public sector research institutions from leading OECD countries or from transnational corporations (TNCs), thus subject to the intellectual property rights (IPR) of the transferring institutions and companies (Seshia 2002; Indira *et al.* 2005). The strong institutional and private sector support for agricultural biotechnology is one characteristic of India's debate on GM crops (Glover 2002; Seshia 2002). Private sector biotechnology associations including the All India Biotech Association (AIBA), the Association of Biotechnology Led Enterprises (ABLE) alongside industrial bodies including the Confederation of Indian Industry (CII) and the Federation of Indian Chambers of Commerce and Industry (FICCI) have all been active in promoting agricultural biotechnology, in promising significant agricultural and food production gains (Scoones 2002) and in promoting the use of 'sound science' as the exclusive criterion for regulation and governance (Newell and Glover 2003).

India's highly contested regulatory system has three tiers. Institutional Biosafety Committees (IBCs) are the first tier of regulation. Housed within research organisations, they provide initial clearance for any research or development activities that involve the use of GMOs in scientific experiments or trials. The second tier is the Review Committee on Genetic Manipulation (RCGM). Housed in the Department of Biotechnology (DBT), it authorises approval for small-scale field trials of domestically produced and imported GM varieties, with responsibilities for the monitoring and evaluation of data and with specific criteria for biosafety, agronomic performance and environmental impacts. Applications for approval, having been sanctioned by the RCGM following the results of field trials, are then scrutinised by the third and final tier of regulation, the Genetic Engineering Approvals Committee (GEAC), housed in the Ministry of Environment and Forests. Renamed the Genetic Engineering Appraisals Committee in 2010, the GEAC is responsible for granting permits to conduct experimental and large-scale open field trials, for evaluating and monitoring such field trials and, ultimately, for granting approval for the commercial release of GM crops. Even though the regulatory procedures for agricultural biotechnology were scrutinised by a government appointed task force in 2004 (Swaminathan 2004), and new arrangements suggested under a proposed but as yet unratified new regulatory body, the Biotechnology Regulatory Authority of India (BRAI), there have remained few opportunities within the regulatory apparatus for the participation of consumers, environmental movements, farmers associations, or input from traditional tribal or local cultures (Glover 2002). Alongside scientific input, participation in regulatory decision-making processes has been dominated by public sector actors, by public and private sector research interests and by the corporate sector (global and domestic).

Questions about public participation, about cultures of risk and India's capacities for resilience, as well as about liability and the need for ethics in technological appraisal, were part of the science policy debate on agricultural biotechnology in India, especially in the aftermath of the Bhopal gas tragedy (Jasanoff 1995), and following related debates on the Protection of Plant Varieties and Farmers Rights Act (PPVFR) in 2001, the Biological Diversity Act in 2002, and the proposed Seed Bill in 2004. But the regulatory system that was put in place on GM crops, the emphasis of public and private sector agricultural R&D on GM crops, and the elite actors who commanded scientific and political authority, seemed largely impervious to such questions of liability, cultural and biological diversity, democratic norms and so on (Visvanathan and Parmar 2002; Stone 2007). In the 2000s, India's GM crop debates thus came to be held in two highly polarised mainstream camps. The first was led by the Indian state and included the public sector agricultural R&D system, the agriculture biotechnology industry, and large-scale and middle-scale farmers; the second was led by civil society actors, some state governments and several marginalised stakeholders, and included peasant and smallholder farmers, women, environmental activists, agro-forestry and pastoral communities. We now set out a brief chronology of the debate on GM crops in India.

A brief history of the debate on GM crops

India's GM crop and food debate approached a climax in mid-2014 (the time of writing), following the decision by the then Minister for Environment and Forests, Veerappa Moily, to grant approval for open field trials of 14 food crops in March 2014 (Mohan 2014a). Having revoked the 2013 Supreme Court's order to ban field trials of GM crops indefinitely in the absence of adequate and satisfactory regulatory procedures, this approval by the union government has been heavily criticised by environmentalists and academics for disregarding democratic decision-making procedures, for disrespecting prior scientific evaluation which have highlighted potential long-term consequences (impacts on society and the environment) and for discounting eco-friendly alternatives (Shiva 2014). This latest intervention is but one instance in the complex and ongoing controversy that has surrounded the regulation of GM crops in India over more than a decade and a half.

GEAC approved genetically modified cotton seeds in 2002 for commercial use. This was in effect a retrospective approval, as a pragmatic response following evidence of widespread illegal cultivation in Gujarat, in 2001, of the *Bt* cotton varieties of Mahyco Monsanto Biotech (MMB) which at the time was under field trials, awaiting formal approval by GEAC. During 2003 and 2004 much effort was devoted to compiling evidence for the 3-year review of *Bt* Cotton in 2005. With over 600 hybrid lines and more than 35 seed companies and public sector organisations engaged in developing and marketing *Bt* cotton, this came to occupy centre stage in India's seed sector, and the GM crop debate in the country. For their promoters, the approval and adoption of *Bt* cotton became an indicator of the success of GM crop technology, of its acceptance by farmers, and of associated economic and social benefits (Gandhi and Namboodiri 2004; James 2008; Karihaloo and Kumar 2009; Ramaswami and Pray 2007). Nevertheless, academics and environmentalists expressed concerns about the impact assessment studies that were conducted on *Bt* cotton (Arunachalam and Bala Ravi 2003; Sahai 2003; CSA-IIED 2005), and several civil society organisations initiated and completed their own alternative assessments of the impact of GM crops, including *Bt* cotton (see Qayum and Sakkhari 2006; CSA 2005).

The legitimacy of the *Bt* cotton review process was questioned by a variety of actors. It was claimed that the study sites chosen for *Bt* cotton field trials did not cover the entire spectrum of cotton-growing areas in India, that the data collection and analysis were flawed and that the reported yield gains from the adoption of *Bt* cotton was scientifically weak (Arunachalam and Bala Ravi 2003; Sahai 2003). The civil society organisations, The Deccan Development Society (DDS) and the Andhra Pradesh Coalition in Defence of Diversity, conducted their own three year study (2002–2005) in four different cotton-growing districts in Andhra Pradesh and what is now called Telengana (Warangal, Adilabad and Nalagonda and Kurnool) covering 440 farmers growing *Bt* and non-*Bt* cotton under irrigated and rain-fed conditions (Qayum and Sakkhari 2005). The study concluded that on smallholder farms under rain-fed conditions, *Bt* cotton yielded nearly 30 per cent less than non-*Bt* cotton, there was on average a 7 per cent cost reduction of pesticide use associated with the adoption of *Bt* cotton and that earnings derived from non-*Bt* cotton cultivation were on average 60 per cent higher than on those with *Bt* cultivation. Increasing numbers of farmer suicides were further attributed in part to *Bt* cotton for reasons associated with the added expense of *Bt* cotton seeds, accompanying indebtedness, agronomic failure and under-performance. Nevertheless, the area of cotton cultivated using *Bt* seeds continued to grow dramatically to over 90 per cent of the national cotton crop, leading to the disappearance of many non-*Bt* varieties of cotton from the marketplace, and where a few organic cotton producers, including organised ones like Maikal cotton, remain the sole groups who retain access to local and traditional cotton varieties.

In 2006, the Government of Andhra Pradesh filed a case against Monsanto under the Monopolies and Restrictive Trade Policies (MRTP) Act, accusing the firm and the union government of charging excessive royalties on its *Bt* cotton hybrids (Das 2006). For the first time in the history of Indian agricultural science policy, an individual state government had litigated against a multinational company, in constructive articulation of its own policies. Such an action followed moves by Sikkim, Karnataka, Uttarakhand, Meghalaya, Andhra Pradesh and Kerala state governments to develop and promote their own state agricultural policies through their respective state legislative assemblies and cabinets, including a prioritisation of organic farming (Raina 2013). This articulation and promotion of an alternative agricultural policy at the state level had added political significance in the context of India's Eleventh Five-year Plan (2007–2012), which allocated for the first time 25 per cent of its allocations for agricultural development directly to state governments, for use by them for location specific agricultural schemes or programmes.

The voices of individual state governments have become an important new feature in India's GM food debate. In 2009, *Bt* brinjal – aubergine, a crop indigenous to India – was approved for commercial release by GEAC following field trials in 2008. One of the central concerns of Indian farmers was to protect the diversity of aubergines grown in the country, which is a centre of origin of the crop, and home to hundreds of wild relatives of the species. India is the largest producer of aubergines in the world, growing more than 4,000 varieties. *Bt* brinjal is a product of the Maharashtra Hybrid Seed Company (Mahyco), which is a partner of the US multinational corporation Monsanto.[1] State governments and activists were concerned that the adoption of *Bt* brinjal would be accompanied by the same kinds of problems that accompanied the adoption of *Bt* cotton: that it would create a 'fad' and be responsible for subsequent agricultural deskilling (Stone 2007), that it would lead to a loss of traditional crop varieties as happened in the case of cotton, and that it would lead to the possible expression of tropane alkaloids (poisonous if consumed) in the brinjal fruit as an unforeseen consequence of the genetic manipulation process and to expressions of toxicity in the plant as has been shown to be evident in *Bt* cotton plants (Kranthi *et al.* 2005).

The concern about a GM food crop, articulated through experiences with a non-food GM crop (*Bt* cotton) was noted and the union government of India, through its Ministry of Environment and Forests, organised a series of public hearings, with active and inclusive participation of all stakeholders, including pro- and anti-GM actors. The Minister, Jairam Ramesh who oversaw these public hearings and the evaluation of associated evidence collected in early 2010, stated that 'public sentiment is negative', and that it was his duty as Minister 'to adopt a cautious, precautionary principle-based approach' leading to a proposed ban by the Ministry of Environment and Forests on the commercialisation of *Bt* brinjal. But the pressure to apply 'sound science' in decision making – rather than to rely on public hearings of the opinions, experiences, and fears of farmers, consumers, ecologists, food industry representatives and an under-informed public – led Jairam Ramesh to request the informed scientific opinion of six Indian academies of science, to evaluate the desirability of the commercial release of *Bt* brinjal. The academies produced a report, signed by the presidents of all six academies of science, recommending that *Bt* brinjal be approved for commercial release, given that it was evaluated as being safe for human consumption and with negligible environmental effects (Indian Academy of Sciences 2010). However, on finding that sections of the report had been plagiarised from an earlier report prepared by a US-based lobbying organisation for the biotechnology industry, and that in addition the report had not addressed certain questions on toxicity, nor industry control over the food chain, Jairam Ramesh dismissed the report, and declared a moratorium on the release of *Bt* brinjal (Menon and Siddharthan 2010).

In 2012, the Parliamentary Committee on Agriculture, following widespread consultation with various stakeholders in the debate including farmers, farmer union leaders, biotechnology industry representatives, relevant departments in the union government, state governments, scientists and civil society members, issued a report on GM crops in which they claimed that existing regulatory mechanisms were highly inadequate, reflected 'a pro-industry tilt' and were riddled with conflicts of interest (Committee on Agriculture 2012; PRS 2012). The report recommended a complete overhaul of the regulatory system, a ten-year moratorium on field trials of all GM food crops in India and the termination of all ongoing trials of transgenic crops. The Technical Experts Committee (TEC) appointed by the Supreme Court and comprising scientists from top public research laboratories and academic institutions changed the ten-year moratorium on field trials of *Bt* transgenics to an indefinite moratorium on GM food crops. The rationale given for this decision was that the Indian regulatory system contained major gaps which had to be addressed before further field trials could be allowed.

In February 2014 the new Minister of Environment and Forests, M Veerappa Moily granted permission to seed companies and agriculture research institutes to continue with the field trials of different varieties of GM crops which had previously received clearance from GEAC, arguing that prior decisions by GEAC were not bound by the Supreme Court's moratorium on field trials order, but emphasising that research institutions still needed to seek permission from their respective state governments (Mohan 2014a). Moily's decision was severely criticised by the Parliamentary Panel on Agriculture who argued that any new 'research and development' on transgenic varieties of crops should be done only in strict containment and that field trials should not be undertaken until the government puts in place adequate 'regulatory, monitoring, oversight, surveillance and other structures' (Mohan 2014b).

Among the major allegations that GEAC faces are concerns regarding the breadth, quality and independence of the expertise that it uses in decision-making processes. Expertise is claimed to flow too freely between regulatory authorities and the product developers, partly because there are few experts with relevant expertise in genetic engineering, molecular biology, genomics and environmental impact assessment (Committee on Agriculture 2012; PRS 2012). Ananda Kumar, the plant molecular biologist from the Indian Agriculture Research Institute (IARI) who was responsible for the development and field trials of *Bt* brinjal, was, for example, a member of the GEAC committee which approved the crop for commercial introduction in 2009 (Menon and Kohli 2010), a member of the Inter-Academy panel (Indian Academy of Sciences 2010) that was established in response to the Minister's demand for 'unbiased, scientific opinion', and co-responsible for its subsequent report that was later found to have plagiarised large sections from his own and other previous work (Menon and Siddharthan 2012). Other similar allegations surfaced naming other geneticists, molecular biologists and plant breeders (Goswami 2007).

Each actor in the GM crop debate can be seen to be part of a fairly predictable discourse and engagement process. On the one hand, the Indian state (the union government in particular), formally organised science (e.g. in genetics, plant breeding and economics), farmers in irrigated arable tracts, traders and the seed industry, all have their own established legacies, discourses, practices and past public investments that support their own articulation of India's modernisation project in a manner that embraces the need for GM crops. On the other side, the state governments, other branches of organised science (e.g. involving the environmental sciences, the social sciences, the agronomic sciences and parts of plant breeding and entomology), activists, consumers, marginal and smallholder farmers (especially those who farm in rain-fed, mountain and coastal ecosystems) have always struggled to articulate their local environmental, social, economic and cultural concerns with GM crops. Even though the Constitution of the Republic of India clearly places agriculture as a state subject, even after decades of demand for decentralised decision-making and location-specific natural resource-based research, and even after acknowledging the productivity, economic and ecological gains that can be achieved from a wide range of agrarian alternatives, their voices remain marginal. Ironically, both camps use the same language and categories to express and measure the successes or failures of GM crop, typically appealing to science and scientific risks and voicing the same (and somewhat dismal) metrics of yield, monetary costs, and labour days which, as this volume demonstrates more generally, only poorly and imperfectly capture the social, ethical and political stakes of the issue.

Ethnographic fieldwork with smallholder farmers

India is the world's second largest producer of cotton, after China, producing approximately 18 per cent of world production on approximately 25 per cent of

TABLE 4.1 GM crops in India: chronology of events

Date	*Event*
1988	The New Policy on Seed Development is introduced, aimed at enhancing private investment in the seed industry and liberalising the import of seeds. The Mahyco Monsanto Biotech (MMB) company is founded.
1994	Institutional Biosafety Committees (IBCs), the Review Committee on Genetic Manipulation (RCGM) and the Genetic Engineering Approval Committee (GEAC) are set up as the three tiers of the GM crop regulatory system.
2001	*Bt* cotton is found to be grown illegally in Gujurat.
2002	Retrospective approval of *Bt* cotton in India is granted; over 300 *Bt* cotton hybrids are found across India.
2004	The Task Force on Application of Agricultural Biotechnology submits its report to the Ministry of Agriculture.
2005	The National Biotechnology Development Strategy draft is placed in the public domain by Ministry of Science and Technology.
2002–2005	Publications emerge that cast doubt on the claimed benefits and performance of *Bt* cotton.
2006	The Government of Andhra Pradesh files a case against Mahyco Monsanto Biotech (MMB) under the Monopolies and Restrictive Trade Practices (MRTP) Act.
2007	The authority of GEAC is questioned over allegations of conflicts of interest among its members.
2008	Pushpa Bhargava, the leading molecular biologist of India, having been appointed by the Supreme Court of India to oversee the functioning of GEAC, writes a letter to the Prime Minister declaring that GEAC's regulatory capacities and procedures are inadequate.
2009	GEAC approves the commercial release of Mahyco's *Bt* brinjal (aubergine), but recommends that the union government of India take the final decision. This leads to widespread protests across the country.
2010	The Minister for Environment and Forests, Jairam Ramesh initiates a series of public hearings on *Bt* brinjal. A moratorium is imposed on the commercial cultivation of *Bt* brinjal. The minister asks for a scientific opinion on the desirability of the commercial release of *Bt* brinjal. The report from six national science academies recommends the commercial release of *Bt* brinjal. The report is dismissed by Jairam Ramesh following evidence that large sections of the report have been plagiarised. The minister declares a moratorium on the commercial release of *Bt* brinjal.
2012	A report of the Parliamentary Committee on Agriculture recommends a ten-year moratorium on field trials of all GM food crops in India and the termination of all ongoing trials of transgenic crops.
2013	A committee of technical experts appointed by the Supreme Court of India changes the terms to an indefinite moratorium on GM food crops.
2014	The new Minister of Environment and Forests, M Veerappa Moily, grants permission to seed companies and agriculture research institutes to continue with field trials which had previously got clearance from GEAC but still requires applicants to seek permission from respective state governments.

the world's acreage.[2] Cotton is a highly significant commercial crop in India, providing fibre for the textile industry as well as livelihoods for millions of Indians. The adoption of *Bt* cotton in India has been widespread. By 2013, only one decade after the first approval of *Bt* cotton by GEAC in April 2002, over 90 per cent of cotton in India was planted with *Bt* cotton, cultivated on over 12 million hectares (Kalamkar 2013). Even though it is unclear precisely the impacts of *Bt* cotton on yields and pesticide use, and notwithstanding considerable differences between different states and in different kinds of farming contexts, studies tend to show that *Bt* cotton at least in early usage has led to some increases in yields (through reducing crop losses from especially the bollworm pest), some reduction in pesticide usage (although this is seen to depend on whether farmers continue to use pesticides as a precautionary measure fearing bollworm attack) and some increase in input costs (mostly associated with the increased costs of *Bt* seeds; see Gruere and Sengupta 2011; Herring and Rao 2012; Kalamkar 2013). However, the overall picture is far from clear with a few studies finding that *Bt* cotton may have led to reduced yields and less profit per acre than their non-*Bt* counterparts under certain conditions (Sahai and Rahman 2003; Zahoor 2004). Notwithstanding such unresolved uncertainty, the cotton crop is considered to be profitable for the farmers in India and *Bt* cotton has been widely adopted in practice.

The ethnographic fieldwork was conducted between August and November 2013 in the state of Odisha (formally known as Orissa). The fieldwork was conducted with smallholder farmers, women's self-help groups, NGOs, government officials, seed suppliers, distributors and retailers in the Kalahandi district of western Odisha. Kalahandi was a carefully chosen field site in a state that is known for its marginal status, and that is commonly portrayed as merely a natural resource supplier in discussions on the Indian economy. A district infamous till recently for starvation deaths in a country that has had a spectacular Green Revolution, Odisha is one of the Vavilovian[3] centres of origin of rice, India's staple food and most likely the next GM crop to be adopted for implementation.

The ethnographic study was conducted in an organic and a conventional farming village. In both villages, the farmers practiced cotton cultivation in the uplands, and rice cultivation in the lowlands. Organic cotton growers used hybrid high yield varieties (using 'Nuziveedu', 'Shalimar', 'Tulsi', and 'Takat' seeds), while conventional farmers used *Bt* cotton. In the organic farming village producers received support from NGOs through a cooperative. In both villages, the majority of farmers were either marginal or smallholder farmers, cultivating less than 1 or 2 hectares of land. In the organic village we found strong support networks from NGOs and farming associations. We found an increasing prevalence towards the cultivation of *Bt* cotton in the conventional village, especially in upland areas, due to the perception of higher yields and increased incomes. The ethnographic study included interviews, participation in community festivals and weekly markets, and observation of farming practices, production services and support systems from NGOs, private traders, public sector research and extension agencies.

FIGURE 4.1 Map of fieldwork sites in India

Source: http://d-maps.com/m/asia/india/inde/inde34.gif

A typology of pest control practices

In organic cotton farming, farmers applied three kinds of methods for controlling pests:

- *Cultural method* – this method involved the use of trap crops such as castor or marigold flowers to attract the harmful bollworm away from the cotton plants. These farmers deploying this method used plants such as maize for hosting beneficial pests to act as predators, and practised mixed cropping or intercropping agriculture using crops such as red gram, yam or maize to improve the fertility of the soil and increase crop yield. These crops also functioned as a fallback option for the farmers in the event of cotton crop failures.

- *Indigenous technical knowledge method* – this method involved the use of organic pesticides such as chilly garlic extracts. Farmers deploying this method used chilly garlic extract paste, made into a solution and applied on the growing plants. Another example was the Neem Seed Kernel Extract (NSKE), where five kilograms of NSKE was added to 100 litres of water to make a 5 per cent NSKE solution. The solution was sprayed on the plants after thirty days of cotton germination. It acted as a repellent and an anti-feedant, effectively repelling pests and preventing attack, with minimal impact on non-target organisms or on human health. Another method adopted was the use of cow urine to control sucking pests that include thrips, jassids and aphids.
- *Mechanical method* – this method involved the mechanical collection of caterpillars using a hand net or sweeping basket. In addition, a pheromone (scent) was used to trap the *Heliothis* and *Spodoptera* bollworm, by using a lure (in tablet form) to attract the moths. If one moth is destroyed, up to 700 eggs could be prevented from hatching.

In the conventional farming community village, *Bt* cotton seeds were bought from seed companies many of whom had sought to demonstrate the benefits of the seeds by letting the farmers buy them without upfront payment. The claimed success of *Bt* cotton had become a rallying point for the companies to advertise their seeds. Farmers who had been initially sceptical evaluated the success of *Bt* cotton cultivation by comparing the quantity of bale produced per acre in *Bt* cotton fields with local varieties of cotton. In order to get the maximum benefit, our ethnographic research saw farmers using an excess of fertilisers and pesticides, with likely adverse impacts on the long-term fertility of the soil and thus the sustainability of *Bt* cotton cultivation. Pesticides were seen to be sprayed without using proper gloves and masks, threatening the long-term health of the mainly landless agricultural labourers. In interviews with farmers, they indicated that in the absence of any 'safety-nets' that would allow their households to survive in the event of crop failure, they felt they had to use considerable quantities of pesticides on *Bt* cotton to be 'on the safe side'.

Economic and socio-cultural considerations surrounding GM crops in India

Bt cotton has become popular in the Indian countryside partly as a result of extensive and aggressive marketing from the seed companies, through 'demonstration' distribution of loans and through the delivery of the whole package at the doorstep of the farmers. Though the cultivation of *Bt* cotton did appear to generate significant profits initially (Herring 2007; Qaim and Kouser 2013; Stone 2007), over the years, the cultivation of *Bt* cotton has been affected by increased pest attacks (e.g. from white fly and sucking pests) which has begun to impact on the profitability of the crop. During our field research we found that some farmers were looking for alternatives but reported that they were experiencing a lack of choice. Farmers were finding it difficult to return to earlier forms of farming, and that previously available local varieties including indigenous seeds were no longer easily available (except for those which have been saved through seed-banks or by local farmers). In Odisha, and Kalahandi in particular, farmers who had received the least support from formal credit, infrastructure and other public capital investments considered *Bt* cotton an appealing investment, not least because it was seen as an option that would give them then ready access to upfront cash for recurring household expenses (albeit at the expense of becoming indebted).

Cooking is a social practice in India that influences the perception of GM food crops. Many status differences continue to be expressed in terms of ritual purity and pollution through India's still enduring caste system. Broadly speaking, high status is associated with purity and lower status with pollution. If a person is polluted by eating food that is not appropriate to his or her caste status, this will have ritual repercussions. When we raised the question of GM food with our research participants they pointed out that in a hypothetical situation where a GM crop was produced using DNA from chicken, it would not be suitable for 'pure' caste women. At the same time, they opined that a GM tomato with a gene derived from fish would be appropriate for consumption. One could therefore suggest that, in principle, local religious cultures do not call for a blanket rejection of GM crops. Each crop will be considered in the context of purity and pollution rules for each specific caste in each particular region and social context.

At the same time, when we asked farmers whether they would welcome the introduction of *Bt* rice, many responded that they would be reluctant to do so citing two reasons. First, they suggested that in growing *Bt* rice they would face the same problems that they and their neighbours were already facing in the production of *Bt* cotton, such as the loss of local varieties, growing resistance of pests, and increasing dependency on the (global) seed industry. Second, they pointed out that unlike cotton, which was mainly used for the production of clothing, rice was food and therefore was less appropriate for genetic modification for reasons of long-term human health and safety.

Interviews with stakeholders

In-depth interviews with stakeholders were conducted in Delhi and Odisha. All the interviewees acknowledged that the Indian countryside was in a state of change. For the representative from the seed company and the natural scientist (a geneticist), these changes were understood as part of a (natural) process associated with modernisation, urbanisation and the adoption of advanced technology in the agricultural sector. In contrast, the NGO and smallholder farming representatives described changes in the Indian countryside as an agrarian crisis, symbolised by the image of 250,000 farmers that have committed suicide since 1990. This situation was seen as being driven by a deregulatory state and by associated and prevalent neoliberal forms of policy-making:

> See, with this kind of a regime, whether it is the BJP or the Congress, [in relation to] economic policies, there is no difference. So, they are [all] carrying out the [same] neoliberal economic policies. The state is increasingly withdrawing, deregulating all sectors, giving a free hand to the fertiliser industry, the seed industry, the pesticide industry; and the legal framework is being made such that it will be favouring the corporate interest.
>
> *(Representative of peasants' organisation)*

Views on GM crops were similarly divided. The NGO and smallholder farmer representatives perceived GM crops in a wholly negative light and as largely 'a distraction' from alternative forms of sustainable agriculture. For these actors, GM crops had been driven by external interests, approved through opaque decision-making processes and adopted with no labelling in place for consumers. GM crops had led to compromises in biosafety, the creation of superweeds, and the dependency of farmers on global seed companies. Conversely, the representative from the seed company and the natural scientist perceived GM technologies in a wholly positive light. For these actors, GM crops had led to marked 'improvements' in plant breeding through the incorporation of genetic material directly into a plant's germplasm, thus enhancing the in-built potential of a crop variety. In addition, GM crops were perceived to have the potential to meet farmer needs for weed and pest control (e.g. with insect resistant and herbicide tolerant crops) as well as to respond to national needs (e.g. helping to feed a growing population) and global challenges (e.g. global food security). They claimed *Bt* cotton had already led to a significant decline in the use of pesticides by farmers and that existing GM crops were safe.

For the NGO and smallholder farmers' representatives, the missing voices in the debate were those of independent public sector scientists, smallholder producers and (increasingly urban and middle class) consumers. While, for the representative from the seed company, the missing voice was that of farmers. Indeed, they suggested that an assessment of the needs of farmers was a much needed priority. Both NGO and smallholder farming representatives attributed the recent moratorium on GM crops to an increasing sensitivity from the Indian union government to the issue, while the representative from the seed company and the natural scientist interpreted the moratorium as having resulted from government ministries working at cross-purposes, from self-appointed NGOs misrepresenting public opinion and dominating media coverage, and from misinformed natural scientists.

An interesting observation is that both sides tended to mobilise science to support their claims. During the interviews, both pro-GM and anti-GM actors tended to frame their discussion in terms of risk, with pro-GM actors arguing that current processes of regulation and oversight of GMOs guaranteed their safety, and that the anti-GM discourse should be rejected as ill-informed and sensationalist. While, anti-GM actors responded that current science had not proved the safety of GM food crops and that current regulatory and oversight processes were inadequate and compromised. For the environmental NGO representative, the principal problem with GM crops and foods was that current regulatory and governmental oversight processes were insufficiently independent and scientifically rigorous, and that these had been captured by the corporate interests of the seed companies. While, for the representative of the seed company, current regulatory and governmental oversight processes were also judged to be inadequate and insufficiently scientific, but precisely for the opposite reason: that existing regulatory processes had been overly swayed by emotion and ideology rather than by facts, thus unfairly hindering the biotechnology industry to develop technology that responds genuinely to farmers' needs. Both sets of stakeholders thus appealed to science as the necessary force to justify their claims: either that GM crops were safe and that public concerns were emotional ('hysterical' according the natural scientist), or that GM crops were not proven to be safe and that what was required was the active engagement of independent scientists who have 'serious concerns on the way GMOs are promoted in this country … [they are the] silent majority and the reason why they are silent is also because the government in power has a promotional approach towards GMOs' (environmental NGO representative).

Though the religious dimension of the GM issue was mentioned by a small number of stakeholders, it did not on the whole appear to be very prominent in the interviews. None of the anti-GM stakeholders focused their critique of GM crops solely around cultural or religious issues. Vandana Shiva, for example, as one of the leading anti-GM campaigners, stated in our interview that GM crops were likely to alienate the farmer from the seed in cultural terms, but also offered the more conventionally 'rational' arguments in support of her position, including the argument that *Bt* cotton weakens the ability of the plant to resist pests other than bollworm. At the same time, in answering our questions about the future of GM crops in India, both pro-GM and anti-GM actors made references to the colonial experience of South Asia. Thus, while the pro-GM interviewees argued that it was important for India to continue to develop GM science if it was to be taken seriously in the international arena of biotechnology and not to 'lose out' to foreign seed companies, some of the anti-GM actors also used the rhetoric of post-colonial discourse and talked about the importance of keeping Indian seeds 'intact' and avoiding their 'colonisation' by GM seeds from abroad.

Ethnography at a research laboratory

The laboratory ethnography was undertaken at the New Delhi branch of the International Centre for Genetics and Biotechnology (ICGEB). The ICGEB is an international, non-profit research organisation, which was established as a special project of the United Nations Industrial Development Organization and which became fully autonomous in 1994. ICGEB now includes members from over sixty member states, mainly from the countries of Africa, Asia and Eastern Europe. The aim of ICGEB is to conduct innovative research in the life sciences for the benefit of developing countries, as well as to provide educational and research supports for its member states. At the time of fieldwork ICGEB consisted of three main branches, located in Trieste, New Delhi and Cape Town. The Delhi branch is located within the ICGEB Campus in South Delhi, which comprises an area of approximately 16 acres, situated alongside the Jawaharlal Nehru University. The laboratories encompass a main building, a bioexperimentation unit, a biosafety level-3 facility, and a number of greenhouses for agriculture related research. The main research areas at ICGEB in New Delhi include mammalian and plant biology. More specifically, biomedical studies are conducted in virology (hepatitis B and E viruses, human immunodeficiency virus and SARS virus), immunology (biology of the immune response and tuberculosis), development of diagnostics and vaccine candidates for dengue fever, structural biology (development of synthetic antibiotics, crystal structure determination of proteins and polypeptides), basic research and vaccine and drug development for malaria, as well as development of technologies for biopharmaceuticals and for diagnosis of infectious diseases. In the plant biology section, which was the focus of our study, ICGEB projects were focused on insect resistance and biopesticidals, abiotic and biotic plant stresses and crop improvement through biotransformation. ICGEB New Delhi has 36 principal investigators distributed in nine different research groups, funded from a wide range of funding bodies including both national funders, principally the Department of Biotechnology, and international funders that include the Wellcome Trust, the European Malaria Vaccine Initiative, the European Commission, the International Aids Vacine Initiative, the National Institute of Health, the Bill and Melinda Gates Foundation, Dupont and PepsiCo.[4]

Fieldwork was undertaken during a 20-day period in September 2013 in the plant molecular biology laboratory. The laboratory had five principal investigators, over twenty postdoctoral research fellows, sixteen PhD students and four technicians. Research conducted at the lab included a wide range of projects that ranged from the production of plants resistant to herbicides, plants with in-built insect resistance, crops resistant to abiotic stress (dry conditions and salty soil) and rice with improved nutritional value (an analogy to Golden Rice). The main crops for the laboratory were rice, potatoes, tobacco, cotton and tomatoes. The topics of the research projects were determined by the principal investigators; postdoctoral research fellows had applied to work on specific projects with a particular principal investigator; while PhD students had applied to ICGEB and, when accepted, then choose a principal investigator to work with, eventually being awarded their doctorates from Jawaharlal Nehru University. Most respondents noted that their current research was funded mainly by the union government's Department of Biotechnology.

Participant observation in the laboratory was focused on the work on two principal investigators (PIs) and their postdoctoral research fellows and PhD students. The research team of one of the PIs was developing work on the creation of herbicide and abiotic stress resistant rice, while the other PI was developing a project aimed at enhancing the nutritional content of rice. All the scientists we interviewed, irrespective of their position in the laboratory, had a strong pro-GM stance. All respondents expressed disappointment at the recent introduction of the moratorium on GM crops trials. Most supported the argument that their research was safe and that GM research was a logical step forward in the sustainable development of agriculture. As one of the PIs put it in the very first interview we conducted after the aims of our project were described to him:

> If you want to know if I am pro-GM or anti-GM I can tell you straight away that I am pro-GM because this is the future. What geneticists are doing is hardly different from what breeders have been doing for a very long time and what we are doing is safer.
>
> *(ICGEB researcher)*

At the same time, all scientists agreed that current GM crops were not offering better nutrition than non-GM crops. All the respondents stressed that GM crops were particularly needed in developing countries like India and the argument that they put forward was that without GM crops India would not be able to feed its growing population. As one respondent put it:

> 'Going organic' may be good for Europe where there is surplus of food, but not for India, where many people are starving and where pest control is particularly difficult because of the climate. Using GM crops would be much healthier than using pesticides which is common practice now.
>
> *(ICGEB researcher)*

When discussing whether GMOs were safe to use, all respondents emphasised the importance of developing and following strict safety protocols. However, again, in conversations about biosafety, references were often made to the specifics of the Indian context of food production, which included a hot climate, a large population, wide-spread poverty and a lack of effective regulation of pesticide use. For instance, when we asked whether GM food should be labelled as such when offered to consumers, one PI argued the following:

> Sometimes they have to spray crops up to 90 times with poisonous chemicals. So, how come you have to put a label on a GM vegetable saying that it is a GM vegetable, but you don't label 90-times-sprayed vegetables as '90-times-sprayed'?
>
> *(ICGEB researcher)*

The rhetoric of our respondents oscillated between the position that emphasised that GM food was safe and the one that argued that GM crops were needed primarily in developing countries which could not afford non-GM food, and that therefore it was 'the lesser of two evils' when compared with starvation and the (over)use of pesticides. Interestingly, like activists in the anti-GM camp who argued that GM crops were harmful for India as they represented the colonisation of the Indian countryside by foreign companies, such as Monsanto, the pro-GM scientists from the lab also framed their discourse about GM crops in terms of postcolonial critique. Several respondents based at ICGEB suggested to us that India strategically needed to continue to develop GM research and to undertake field trials in order not to fall behind in this particular area of biotechnology, which, they argued, was the technology of the future. Many interviewees noted that while they appreciated that the Indian Department of Biotechnology continued to fund their lab work despite the then recent moratorium, they were concerned that without field trials Indian GM science would fall behind, and young scientists would lose interest in this research, as they could not see the results of their work either in the fields or in the supermarket. This rhetoric is reflected in a letter sent by the eminent biologist Pushpa Bhargava (often regarded as the architect of modern biotechnology in India) to the Prime Minister back in 2008, who observed that:

> as India is primarily an agricultural country, with 60 per cent of its population deriving its total income from agriculture and agriculture-related activities, it would cease to be a free country if its agriculture is brought under the control of foreign multinational companies through control of seed and agrochemical production.
>
> *(Bhargava 2008)*

For an extension of this argument on freedom, see the commentary by Michael Northcott in Chapter 13 of this volume.

All respondents shared the opinion that the voice of scientists had not been adequately heard in the GM crops debate in India, and argued that the government had imposed a moratorium on growing GM crops without having conducted a proper consultation with scientists, including those who have been pioneering laboratory research. The anti-GM position was construed by our respondents as ignorant. Many scientists also argued that the reason why existing GM crops (*Bt* cotton) did not work for the farmers as they should was because the farmers had not been not following the necessary and relevant guidelines (e.g. creating the required GM-free buffer zones around GM planted fields). Each interviewee argued that the general public needed to be educated about GMOs and that they would be happy to engage with the public and the mass media more, but did not have access to necessary channels for that. Scientists saw anti-GM NGOs as their main opponents and argued that theirs had been the voice that was heard most in GM food debates in India. When we asked whether they had ever received any negative responses to their work from religious groups, they suggested that that was not the case. They were aware of ethical problems that could arise out of transgenic research involving genes taken from animals and inserting them into plants (leading to the potential violation of the dietary requirement for vegetarians for some caste groups) and argued that this kind of insertion could be easily avoided. At the same time, when asked to explain their choice of working with GM crops, most respondents replied that their goal was to improve Indian agriculture and to benefit society. This is how one PI explained the potential social benefits of his work on herbicide tolerant plants:

> You see, we don't want to be using labour any more to weed plants. India is known to be a country of cheap labour and we want to put a stop to this. Weeding is very labour-intensive and time-consuming. Therefore, we have to use herbicides, otherwise you have to weed rice manually. My job is to develop plants that are tolerant to herbicides. This way, farmers could still use herbicides but they will only be killing weeds and not my plants.
>
> *(ICGEB researcher)*

Focus groups with lay publics

This part of the study examines Indian lay public responses to genetically modified crops and foods. The research aimed to understand the perception of different groups of lay publics, grouped for the purposes of this study as professional women, students, housewives and householders. The research took place across different locations in the Kalahandi district of Odisha. Participants were of different age groups and social classes, and since they came from different backgrounds, their understanding of GM crops and food also varied. Each group was composed of between 6 and 10 participants. The first group, consisting of students drawn from different disciplines, offered an interesting debate on GMOs. The group was broadly divided into pro-GM and anti-GM participants, and this informed their responses to the scientific basis of the GM debate, the social and political controversies and the likely benefits seen to be derived from the use of GM products. The second group consisted of professional women engaged in project work, administration and teaching. The third focus group was of women from rural settings, currently engaged in various self-help groups (SHG). The last group consisted of householders who were engaged in farming activities, and who were actively involved in grassroots organisations. The materials used for the focus group discussion included posters with various reports on the issues posed by GMOs, designed to elicit responses from the participants on the controversy of GM crops and foods from a range of perspectives. The debate revolved around technology of GM, current applications in crops and foods, health issues related to GM foods, environmental impacts, governance and economic feasibility.

Initially the discussion revolved around the ways in which the GM debate had been presented in the media in the context of wider concerns about food and agriculture. The participants raised the issue as to whether GM crops and foods had nutritional benefits. They also raised concerns over the hazards of the overuse of pesticides as well as the scientific uncertainties associated with the risks of genetic manipulation. Most of the lay publics who were also farmers raised the issue of seed preservation and exchange. They expressed concern over the introduction of new GM crop varieties, and whether this would lead to the demise of traditional varieties. They further raised the issue of the economic feasibility of growing GM crops, and whether it would be sustainable in the long run. Many of the participants' responses seem to revolve around the issue of 'seed sovereignty'. They were concerned about how GM crops could lead to dependency on 'outsiders' and on seed companies. The householders and housewives, who were mostly farmers, were concerned about increased pest resistance in *Bt* cotton. They also expressed concern on the impact of GM crops on the ecology and health of the soil.

Except for the discussion in the students' group, most of the responses on GM crops and foods were largely negative. The majority of concerns of the participants related to the likely side effects of introducing GM crops and foods, as reflected in the concern of one of the participants in the women's professional group, reported below:

> With hybrid [seeds] also, you are trying to merge two different kinds of species, right? But I think this thing [GM technology] goes a little beyond this, because this is inter-genus you know, [and includes] bacteria and plants. Or so, I think, it also makes me think of our mythology, you know, Mahabharata and all that, we have so many different kinds of ages … makes you feel that way also, I find. And it becomes difficult later to control, this kind of, if again, mutation can arise. Something … anything can happen. So maybe.
>
> *(Professional woman)*

There were also concerns expressed about the accelerating and sensed 'excess' speed associated with contemporary scientific and technological innovation, especially in relation to GM crop research and in particular in relation to those proposed uses which were not seen to be responding to genuine social need. One of the participants stated:

> We are going very fast. You are trying a lot of things, as long as you know when a gene is inserted, so that some cancer doesn't happen, or some serious thing is being prevented. Till that, it is fine. But if we are just doing it for pleasure, to see if green things become red and red things become yellow, then I don't know what will happen in the future.
>
> *(Professional woman)*

A number of participants agreed that GM crop technology should not be used for superficial consumer desires (as opposed to genuine needs), drawing boundaries over the kinds of application where GM technology should or should not be applied (e.g. over claims that GM technologies should not be used merely for artistic or aesthetic appeal). There seemed to be general concerns as to whether GM technologies were tampering with nature. They believed that GM technology may be accelerating evolutionary processes with unknown effects. The participants questioned whether the human body could adapt to new kinds of food, produced through genetic modification techniques. For most participants, the use of GM technology for agricultural sustainability purposes appeared as a contradiction in terms.

Many of the participants in the rural farming householder group agreed that genes inserted from one vegetable plant to another may in principle be acceptable. However, genes transferred from animals to food crops would be less acceptable, as they believed that this would go against their religion and tradition. One of the participants was asked whether she would eat vegetables injected with a chicken (Oriya: *kukuda*) gene; she responded that she would not eat such vegetables as this would go against her traditions and religion. For the women in this region of Odisha, chicken is considered to be a food taboo. Only male members of the family are permitted to eat chicken and eggs. Interestingly, one of the participants said that she might take the kukuda-injected vegetables without knowing, but she cannot take them with full knowledge. According to Ramya,[5] both the female and male members of her family do not eat chicken. Indeed, she would not touch *kukuda*-injected vegetables. She asked: 'Who would wash the plates if the male members in the family take such food?'

Another of the participants from the group of rural householders, Kumar, expressed a view of being against GM crops because such a form of agriculture does not allow for indigenous seeds like pulses and paddy to be saved and utilised in the next season, which would increase farmers' dependency on outsiders, including seed companies. Moreover, he reported that with the cultivation of *Bt* cotton, there had been an observed increase in pests, some of which had become resistant to pesticides. Another participant from the group of rural householders, Parbat, doubted the germination potential of *Bt* or any outside cottonseeds; rather, he pronounced himself to be in favour of indigenous seeds.

The majority of the participants expressed a negative opinion to GM crops and foods (current and proposed), and this was to do largely with issues of trust and uncertainty. Many of the participants were sceptical of the role of foreign multinational companies and of the scientists who work for them. Many of the participants seemed to perceive that all GM food was in the hands of outside corporations. According to them, even if research were to be undertaken in government research institutions, the eventual users and beneficiaries of the research would be the outside corporations. They argued that GM crop research in government research centres (and associated downstream products) may or may not be publicly acceptable, but the public in any case would not be given a choice. However, by contrast, those minority participants who had a natural science background or who had specialist knowledge in biotechnology argued that innovations in science (including in GM) would be able to solve many current human problems, including the current crisis in agriculture. They suggested that GM crops, especially those that are bred to be drought-resistant, could save farmers from famine-like situations. They also suggested that saline tolerant GM rice could be grown in coastal areas, which would ultimately increase the area under rice cultivation. However, many participants observed that there seemed to be a disconnect between what happens in the lab and what actually happens in the field and raised the issue of the need for a stronger regulatory framework, which could effectively regulate GM R&D to ensure it met the public good at the grass-roots level.

Many of the participants believed that the core responsibility for effective GM crop regulation lies with the government. Regulation of GM research and products was seen to be effective only when there was transparency and when open debates on health and environmental impacts were allowed to take place. Much of the current impasse was seen to arise when there is dissent within the scientific community and with government appointed committees. Once dissent within the scientific community becomes known, the media quickly picks up and publicises it. This was seen to create considerable confusion in the minds of the public, as they cannot differentiate between what is true, and what is false. Much of the current disagreement on GM crops and foods had arisen, our participants believed, due to outstanding questions on the risks of GM crops and foods to human health and the environment. There was perceived to be a need for an open debate on national television, where people could hear both sides of the argument. This, according to some participants, would dispel much confusion in the minds of the public.

NEELA: I think there is a need for a wider debate – with a lot of types of people who come up with their own angles on GM research, who are knowledgeable. We are not knowledgeable. At least I am not that knowledgeable. We have opinions because of certain things we've heard or discussed or … Are there people who can tell the truth? Or are they willing to tell the truth? From different angles, will they will be able to come to the public debate.

SUSHMA: This discourse also starts because there is some vested interest of one or the other. Either it is started by Greenpeace, Greenpeace has its own agendas, you never know [smile]. That is what I said. So many things are there in the media that you really [are] confused with. What GM crops are? Are they good? Are they bad? Should we propagate …? Everything is so confused.

(Professional women)

Within the groups there was considerable discussion as to whether they would feed GM rice to their family members, if at all, if GM rice was made available in the market. Even if it was supposed that GM rice is cheap, of high quality and of good taste, participants' responses remained ambivalent, reflecting their sense of uncertainty or fear over GM food crops. As one of the participants from the group of professional women put it: 'There is a bit of that reluctance … That niggling fear that something might go wrong'.

Deliberative workshop with stakeholders

The Indian deliberative workshop was organised across two days. On day one, the preliminary results of the Indian field research were presented, followed by a deliberative session with the workshop participants. On day two, a selection of key stakeholders gave formal paper presentations, followed by plenary discussion. The participants were drawn from organisations and governmental agencies representing a broad range of stakeholders that included scientists, farmers, NGOs and activists, academics, indigenous and women groups. The following organisations were represented: Greenpeace India, Gene Campaign, All India Kissan Sabha (AIKS), University of Delhi, National Agricultural Innovation Project (NAIP) under ICAR, Association of Biotechnology Led Enterprise – Agriculture focus Group (ABLE-AG), Bharat Mata Self Help Group, Chetna Organic Farmers Association, Agri-Business Management College of Agriculture, Jawaharlal Nehru University, Centre of Social Markets, Kerala Agricultural University, Indian Institute of Chemical Biology (Council of Scientific and Industrial Research), International Competence Centre for Organic Agriculture, Consumers' Forum, Department of Anthropology, Durham University, SciDev.Net, National Institute of Science, Technology and Development Studies (NISTADS), Farmers' Rights and Monsanto Holdings Ltd.

Reflecting on the science, technology and society interface, the workshop participants pointed to a disconnect between scientific practices and imaginaries in the lab on GM crop research and in situ practices in the field. For the participants, farmers were not passive recipients or agents of a technology. They change, modify and improvise technology (including GM) to suits their own conditions and needs. For instance, farmers were found to often use detergents or shampoo to ensure the quick and smooth flow of pesticide solutions through the sprayer, helping pesticide applications stick longer on the leaves of the plants, thereby making it more effective. At the grassroots level, we found a substantial difference in perception between the application of GM crop technologies for cotton cultivation and the application of GM technologies for food crops. The perceptions of farmers and wider publics were seen to change dramatically when responding to the application of GM technologies in food crops. It was further observed that while plant-to-plant transfer of genetic material may be acceptable (both for farmers and the wider public) in principle, the transfer of animal-to-plant genes was not. The results of the fieldwork and the workshop's deliberations suggest that there is a further need to explore the socio-economic and cultural aspects of the GM debate to better understand the factors that mediate public acceptability.

The majority of the workshop participants were opposed to the introduction of GM crops. Following deliberation on various aspects of GM crops and foods, participants discussed the need for a strong regulatory framework at the national level and for effective monitoring at the grassroots. The majority of the participants also suggested that active citizen participation was necessary as was a holistic approach to regulation and governance. Following in-depth deliberation in breakout groups, each of the groups presented their views of what they considered to be the strategic priorities and action points for GM crop governance. The strategic priority for Group 1 was to advocate a constructive and inclusive critical engagement with the technology using public and stakeholder consultation as a technique to ensure the technology responds to local needs. Suggested action points included: calls for wider accountability by public funded agricultural research bodies to be oriented towards social needs, and for governance institutions, including the national agricultural research system headed by Indian Council of Agricultural Research (ICAR) and other associated bodies, to be properly concerned with health, food, nutrition and the agricultural production impacts of GM crops. In addition, the group stressed the importance of accommodating different framings of the issues surrounding GM crops, including cultural and religious sensitivities.

The strategic priority for Group 2 was to call for farming communities to be provided with the capacity to manage their own seed systems. Such capacity should include storage, the provision of warehouses, proper scientific breeding and the maintenance of local knowledge systems. There was also the perceived need for seeds to be regularly sown so that they can adapt to climatic change. The suggested action points for the group were to keep the debate on GM foods and crops ongoing and to make decisions based on good meso-level data. Another strategic point suggested by the group was to promote a range of alternative, appropriate farming systems, including agro-ecological systems.

The strategic priority for Group 3 was to question the argument that the development of GM crops provides the answer to India's strategic food security needs. They called for the debate to be widened and deepened, to involve listening to a wider range of stakeholders, and for the focus to be taken out of the scientific arena as the sole voice of authority. Suggested action points were for greater accountability, transparency, and democratisation of the regulatory system. There were some strong disagreements during the workshop deliberations, mainly between those holding pro-GM and anti-GM positions. However, the main overarching strategic action point that was developed in the workshop was agreed without much difficulty by all the participants (across the three breakout groups). This was:

> To sustain the adoption of a 'science-plus' approach, ensuring the participation of the heterogeneity of stakeholders, and accommodating different framings of the challenge – all implicitly equal. Doing so will help promote a range of alternatives, socio-culturally appropriate farming systems, well grounded in the diverse agro-ecological contexts of India.

Conclusions

We now briefly summarise the key findings from the India case study. First, we reviewed the debate on GM crops in India. We identified the trajectory of the debate and the factors that led to the ongoing resistance to the adoption and take-up of GM crops in India, culminating in the 2013 ten-year moratorium. We found that the issue has been hotly debated by parliament, by the union government, by NGOs and in the media, much of the debate revolving around concerns regarding the regulation of GM trials and crops. We found that the promotion of GM crops has been encouraged by the union government of India, by the Ministry for Agriculture, and by the wider science and technology establishment. Within this context, even though there have been a few within these organisations who voice concerns about the agronomic, political, economic and ecological implications of GM crops, it has been the NGOs who have spearheaded the articulation of these concerns, with some success.

Second, we presented fieldwork research with smallholder family farmers – both in organic and conventional farming villages – in the Kalahandi district in the west of Odisha. In the organic village we found strong support networks from NGOs and farming associations. We found an increasing prevalence towards the cultivation of *Bt* cotton in the conventional village, especially in upland areas, due to the perception of higher yields and increased incomes. We saw that *Bt* cotton, now accounting for over 90 per cent of cotton cultivation in India, was being aggressively marketed by seed companies, through demonstration projects, the provision of advantageous loans and the delivery of inclusive technological packages. This was perceived as having both positive and negative effects. As well as increasing incomes, the increased coverage of *Bt* cotton was making it difficult for the farming community to access traditional varieties of food crops, including millet, jawar (sorghum) and lentils. Increased incomes came with increased cultivation costs, seed costs especially, and increasing dependence on external agents. Moreover, in recent years *Bt* cotton crops had become affected by increased pest attacks and have led farmers to consider previously available seed varieties. However, farmers find themselves often 'locked-in' to using *Bt* cotton with indigenous seeds no longer so easily available.

Third, we reported on the results of interviews with a variety of local stakeholders involved in the debate on GM agriculture. We found an interesting observation that both stakeholders in favour of GM crops (e.g. representatives from seed companies) and those against (e.g. environmental NGOs) tended to use a similar argument from science: that what was seen as required in both cases was more rigorous science to help settle the issue. For the environmental groups independent science would bolster their claims that GM crops had not been proved to be safe, while for the seed companies science would prove that GM crops were safe and that public concerns were unreasonable.

Fourth, we reported on findings from a laboratory ethnography conducted at the New Delhi branch of the International Centre for Genetics and Biotechnology

(ICGEB) research laboratory. We found that all scientists whose work we observed were opposed to the moratorium and constructed and perceived the position of anti-GM actors as 'ignorant' or aimed at 'publicity' seeking. Scientists' critique of the moratorium was often framed in terms of post-colonial discourse, as they argued that India could not afford the risk of 'falling behind' in the development of biotechnology.

Fifth, we presented research with lay publics on Indian public responses to GM crops and foods. Using a series of focus group discussions, we found the majority of our research participants developed negative views on GM crops and foods. Urban publics pointed out that they did not trust the government and the local authorities to provide a reliable regulatory system for the production of GM crops and therefore would prefer to avoid the consumption of GM food. Our research participants from the urban groups also suggested that the information about GM that was available in the Indian mass media was confusing and that they would welcome better structured TV debates which would provide a forum for both pro-GM and anti-GM actors to present their positions. Rural consumers also expressed negative views of GM crops and argued that using GM seeds was interfering with the preservation of indigenous seeds.

Sixth, we reported on a deliberative workshop, conducted with a range of national stakeholders, set up to explore research findings and how to develop the public debate on GM crops. We found that participants from different categories of stakeholders were eager to engage in a dialogue and emphasised the importance of considering diverse points of views in deciding the future of GM crops in India.

We conclude by making a few final observations. In India, both the pro-GM and the anti-GM sides of the debate have commonly framed their concerns in the form of postcolonial critique: India as the last bastion of the small peasant, India as needing to sustain control over its agricultural resources, Indian science as not affording to fall behind in the global race of biotechnological innovation. In this sense, the case study of India would be first and foremost relevant to the study of GM crop debates in the countries of the global South and societies 'in transition'. However, this insight from the Indian case study may also be useful in exploring responses to GM food in the global North, as it suggests the importance of taking into consideration the historical experiences of the groups that voice concerns over GM and of examining the global and local structural inequalities that surround the production of GM crops.

Another point to make on the implications of our findings for governance is that in future governance debates on GM crops, to ensure that 'marginalised' stakeholders (such as smallholder farmers in the Indian case) are provided with a forum for expressing their views and for feeding their experiences into the process of GM regulation. Here again, it is important to pay particular attention to the way that the structural inequalities of each society under consideration may be placing marginalised groups at a disadvantage in any consultation process. Next, the study elucidates the importance of taking into consideration the specifics of the agro-ecological systems in question where the production of GM crops is debated, and to ensure the survival of a wide range of diverse farming systems appropriate to the agricultural context of the country. And finally, this case study points to the need to be open to the role of new governance actors, in this case the role of state governments, and their ability to reconfigure the terms of the debate, not least through their ability to distribute public funds.

Notes

1 Monsanto has three Indian subsidiaries: Monsanto India, Monsanto Enterprises, and Monsanto Chemicals. In early 1998, Monsanto acquired a 26 per cent stake in the Indian seed company Mahyco.
2 See www.cotcorp.gov.in.
3 A Vavilov centre is a region of the world first indicated by Dr Nikolai Vavilov to be the original centre of origin of a cultivated plant where domestication started.
4 See www.icgeb.org/home-nd.html.
5 All names of participants have been anonymised.

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5

COMPARING GM CROPS IN MEXICO, BRAZIL AND INDIA

Phil Macnaghten

Comparing the national debates

In Chapters 2, 3 and 4 of this volume we reviewed the trajectory of the debate and controversy over GM crops in Mexico, Brazil and India. We found considerable patterns of overlap, but important specificities too. We now comment on points of difference and commonality. In terms of the policy regime we can see close parallels across the three national cases. In all cases, we witnessed in the 1990s the creation of national regulatory bodies set up to regulate GM crops, both to provide technical advice on applications for approvals (for field trails and for commercial cultivation) and to provide specific advice on the risks to human health and the environment from the release of GMOs. The regulatory bodies were principally the National Agricultural Biosafety Committee (CNBA) in Mexico (which later became CIBIOGEM, the Inter-Ministerial Commission on Biosecurity and Genetically Modified Organisms), the National Technical Commission on Biosecurity (CTNBio) in Brazil, and the Genetic Engineering Approval Committee (GEAC) in India. Even though all three committees were set up to include representatives from leading public universities and research institutes, and even though each technical committee was situated within a complex network of variously configured inter-ministerial responsibilities and obligations, this did not provide what Maartin Hajer refers to as 'authoritative governance' (Hajer 2009): in order words it did not lead to decisions, developed through reasoned, open and transparent deliberation, that were seen as trustworthy and as worthy of acceptance by the broader community.

Across all three jurisdictions, we saw the decisions made by these technical committees rejected as biased, unlawful, unconstitutional and lacking in transparency, both by farmers and scientists, and, at times, by judges in court. We also witnessed wider criticisms: that the decisions adopted by these committees were discursively constructed as a threat to smallholder and indigenous agriculture, and that this had promoted (perhaps unwittingly) a form of agriculture in tune with neoliberal policies that (arguably) was not in the national or public interest. Indeed, undeniably there are important and legitimate political, cultural and social dimensions associated with the transformation from conventional crops and traditional husbandry practices to GM agriculture, including the choice of not pursuing alternative options such as agro-ecology. At least first generation GM crops – plants modified to be either herbicide tolerant or insect resistant or both – have enjoyed a particular social constitution: i.e. they imply, or at least are favourable towards, a particular pattern of social relations. As stated earlier, they can best be described as 'mechanisation' technologies that principally help farmers reduce labour costs and farm larger acreages (Buttel 2005). In addition, as analysed in previous research, they have been associated with an oligopolistic industry structure with a largely inflexible and unresponsive relationship with consumers, questionable or indirect consumer benefits, a political-regulatory framework seen by many as facilitatory and compromised, and with an invisible, and possibly irretrievable hazard potential internal to the body (Grove-White *et al*. 2000). Thus, perhaps it is not surprising that the decisions from government appointed technical regulatory bodies have been so mired in controversy. Given that nation states are (more or less) counselled to approve applications for GM crops in the absence of evidence of harm either to the environment or human health (under WTO rules, etc.), and given that the power and authority to oversee this work lies principally with technical regulatory committees, it is to be expected that wider considerations become effectively hidden from public accountability and influence. In other words, in the absence of a framework that can evaluate these wider considerations (including what kind of agriculture we as a society collectively want), important political discussions and debates become conducted through these technical committees in ways that are largely segregated from democratic deliberation.

Nevertheless, such an overarching argument does little to explain why the controversy surrounding GM crops has taken different forms across the three global 'rising power' case sites. Why have GM crops been approved in Brazil with rapid and widespread adoption since 2005? Why have GM crops been less successful in Mexico with a moratorium that continues to remain in place for new applications for GM maize, including field trials? Why in India, with the exception of GM cotton, was a moratorium put in place in 2013 on all GM crops, including for field trials? These are challenging questions on which we have no definitive answers. However, we can point to a set of factors that appear to be relevant. These include:

- the cultural resonance of the crop in question,
- the strength of civil society actors and their (largely ad hoc) discourse coalitions,
- the perceived capacity and integrity of regulatory bodies to undertake their roles,
- the gaze of the global media, the intensity and durability of protest movements,

- the significance of the GM crop to the national economy,
- the extent to which GM can become represented as a symbol for wider struggle,
- the degree and intensity of public engagement,
- the level of reflexivity within the scientific community, and
- the propensity of institutional actors (particularly the legal establishment) within parts of the state to enter into critical dialogue with other parts of the state.

With these points in mind we can revisit each country in turn. In Mexico, the controversy over GM maize came to prominence in 2001 and 2002, following a highly publicised article in the journal *Nature* reporting the flow of transgenes into wild maize populations (the journal later withdrew its support for the paper), setting the scene for widespread and continuous protest. Maize is highly culturally resonant in Mexico, and protests against GM maize came to signify the defence of Mexican culture and identity in the face of unwanted forms of globalisation. The decisions made by regulatory bodies have been seen by multiple actors as compromised and lacking in transparency. They have been contested vocally by NGOs and questions have been raised about their legality. And there has been little sustained effort by institutional actors, including the Mexican state, to engage the public in inclusive debates on GM crops and foods.

In Brazil, the issue came to prominence after 1998 following the intervention from a couple of innovative NGOs contesting CTNBio's decision to approve Monsanto's application for Roundup Ready herbicide-tolerant GM soya, leading to a de facto moratorium. Even though the soya bean had little cultural resonance in Brazil, it attracted an intense protest movement that was sustained up until 2003 when a presidential degree in effect ended the moratorium. Between 1998 and 2003, GM became a symbol of wider struggle against unequal land ownership, US hegemony and neoliberalism. Following the approval of the Biosafety Law in 2005, the coalition against GMOs lost momentum and GM crops became widely adopted. Nevertheless, decisions by the regulatory bodies remain contested even within the relevant regulatory committees, with routine accusations of partiality and bias. Again, there have been limited attempts by institutional actors to engage the public in discussions on GM crops and foods, with some exceptions (a few media initiatives for example), with discussions remaining technocratic and elitist in character.

In India, the controversy over GM cotton began in 1998 with fears that Monsanto's importation of GM cotton would include a terminator gene that would make farmers dependent on foreign seed companies. Despite Monsanto's protestations that this would not be the case, this led to widespread and highly mediatised visible protests where *Bt* cotton became symbolic of a struggle against multinationals, neoliberal logics, the United States and globalisation. Cotton is a symbolic crop in the national imaginary, signifying strength and self-sufficiency for the poor. The regulatory authorities have struggled to maintain authority in the face of inadequate frameworks for public consultation and a lack of capacity in implementing decisions, including a lack of detecting equipment and an inability to deal with the use of illicit GM crops. The formal reason for the 2013 indefinite moratorium on GM crops and field trials recommended by India's Supreme Court was that there were major gaps in the regulatory system. And again, there has been little sustained effort by institutional actors, including the Indian state, to engage the public.

These factors are set out in Table 5.1. The penultimate point to infer from this analysis is that it would be a mistake, even in the case of Brazil, to assume that the current widespread adoption of GM crops means that the issue is settled, or that the decisions by the regulatory bodies are somehow authoritative, or even that GM crops and foods have been accepted by the public. Indeed, given the lack of sustained effort by institutional actors to engage the public across all three cases, it remains the case that most citizens in India, Mexico and Brazil remain unfamiliar with the technology and the issues it raises – a point confirmed in our focus group research with lay publics.

The final point is to note that GM crops have rarely, if at all, been requested either by farmers or consumers. Rather, GM crops have been developed externally and then promulgated by the seed companies in a top-down manner (this argument is developed by Dominic Glover in Chapter 8, this volume). In addition, in Brazil and India, both GM soya and GM *Bt* cotton were found to be grown illegally and then retrospectively approved by regulatory bodies largely for pragmatic reasons. This dynamic subscribes to what von Schomberg describes as a 'technology push': where major stakeholders (e.g. NGOs, civil society, the public) feel they had little influence on the technology, and where governance is focused exclusively on safety, with minimal deliberation on broader environmental, social and agricultural dimensions (von Schomberg 2013). This is an example of what von Schomberg calls 'irresponsible development' and is largely antithetical to the responsible innovation developed in this book (see Chapters 1 and 17, this volume). We now examine comparatively our fieldwork results across the three case countries.

Comparing the field ethnographies

The nine-week ethnographic studies, undertaken in specific rural communities in each of the three case studies, sought to understand the debate on GM crops – GM maize in Mexico, GM soya in Brazil, GM cotton in India – in the context of local farming and food practices. They produced rich contextual detail on socio-cultural dynamics. In Mexico, our research was carried out with mainly smallholder farmers in the Pátzcuaro Lake region in the state of Michoacán. We found that debates on GM maize were situated within the context of an on-going crisis in rural agriculture, compounded by the end of rural subsidies, rising input prices and intense competition from imported cheap grains. Within this context we found strong and enduring social relations around maize agriculture, reproduced by

TABLE 5.1 Factors shaping the controversy on GM crops: a comparison of Mexico, Brazil and India

Country	*Perceived authority of the regulatory agencies*	*Cultural resonance of the crop*	*Intensity of protest movements*	*GM as symbol of wider struggle*	*Degree of public engagement*
Mexico GM maize	*Low* Decisions by regulatory bodies seen as lacking in authority and transparency and judged at times to be illegal	*High* Maize is an integral part of Mexican identity, history and culture	*High* The anti-GM campaign has sustained its presence since 2002	*High* GM maize is constituted as a symbol of the protest against neoliberalism and NAFTA	*Low* There has been little sustained effort by institutional actors to engage the public
Brazil GM soya	*Low/medium* Approvals have been successfully authorised by CTNBio since 2005 leading to widespread planting; but decisions remain contested	*Low* Soya has little cultural significance in Brazil	*High* (until 2003) *Low* (from 2005) Following the passing of the Biosafety Law the protests peter out	*High* (until 2003) *Low* (from 2005) GM crops are situated within an anti-globalisation discourse	*Low* There has been little sustained effort by institutional actors to engage the public
India GM cotton	*Low* Regulatory bodies seen as lacking in transparency and capacity; perceived gaps in the regulatory system led to 2013 moratorium	*High* The fragile thread of cotton is a national symbol of Indian self-sufficiency	*High* The anti-GM campaign has sustained high profile protests	*High* *Bt* cotton is a symbol of a struggle against multinationals and neoliberalism	*Low* There has been little sustained effort by institutional actors to engage the public

systems of local community exchange and day-to-day food and religious practices. Native maize seeds were accorded a special significance, both as family heirlooms passed from one generation to the next and as capital to ensure survival in difficult times. Maize agriculture tended to be practised within the *milpa* system, which helped sustain traditional practices and ontologies and which led to an enduring sense of pride in agricultural labour. Within this context GM maize was seen, unequivocally in our research, as a likely intrusion into traditional practices, with unknown and likely negative impacts. Suspicion was exacerbated by deep and historical patterns of mistrust expressed in the motivations of key actors, notably the government (typically seen as corrupt) and the seed companies (typically viewed as self-interested). Smallholder farmers tended to be ontologically opposed to GM maize, seeing it as artificial, manmade, unnecessary and as a threat to traditional patterns of agriculture.

In Brazil, our research was carried out with smallholder family farmers (some cultivating GM crops, others not) in the western region of the state of Santa Catarina. We found that the region was also experiencing a serious economic crisis, driven by falling relative agricultural prices. We identified that the main option for family farming was seen to lie in the production of GM soya (and GM maize to a lesser extent), and that those who have not adopted GM crops were being pushed to the margins of the productive system. We found those involved in non-GM agriculture – typically smallholder, organic or agro-ecological farming – were choosing not to adopt GM due to their desire to produce high quality, healthy foods both for their families and for (niche) markets. Even those cultivating GM crops often used creole (non-GM) maize for domestic consumption, on grounds of taste and the perception of outstanding safety concerns. Organic farmers also complained about neighbouring GM farms not respecting legally-binding segregation distances, thereby 'intoxicating' their farms with herbicides. For those adopting GM crops, perceived advantages were less labour, ease of application and better productivity and prices. We found evidence of conflict between farmers cultivating GM crops and technicians from the seed companies, each blaming each other for the increasing prevalence of glyphosate-resistant weed species (glyphosate being the herbicide designed to treat Monsanto's Roundup Ready herbicide tolerant GM crops).

In India, our research was carried out with smallholder family farmers – both in an organic and an conventional farming village – in the Kalahandi district in the west of Odisha. In the organic village we found strong support networks from NGOs and farming associations. We found an increasing prevalence towards the cultivation of GM cotton in the conventional village, especially in upland areas, due to the perception of higher yields and increased incomes. We saw that *Bt* cotton, now accounting for over 90 per cent of cotton cultivation in India, was being aggressively marketed by seed companies, through demonstration projects, the provision of advantageous loans and the delivery of inclusive technological packages. This was perceived as having both positive and negative effects. As well as increasing incomes, the increased coverage of *Bt* cotton was making it difficult for the farming community to access traditional varieties of food crops, including millet, jawar (sorghum) and lentils. In recent years *Bt* cotton crops had become affected by increased attacks from bollworms and other pests and have led farmers to consider previously available seed varieties. However, farmers found themselves often 'locked-in' to using *Bt* cotton with indigenous seeds no longer so easily available.

Comparing the three cases, it is clear that GM maize in Mexico represents a unique case. The cultural resonances surrounding maize clearly indicate that any introduction of GM maize, especially in the southern states, would most likely be perceived as a threat both to local traditional practices and to a historically situated sense of identity. In Brazil, on the other hand, soya has little cultural resonance (much of it is produced for export and for animal feed in any case) and there was little sense of GM soya as violating local senses of identity. India represents perhaps a more in-between case. Even though cotton is represented as a potent symbol of Indian national identity and self-sufficiency, in our local agricultural communities, *Bt* cotton was rarely depicted as embodying a threat to traditional ways of life. In India and Brazil, GM crops had been aggressively (and successfully) marketed by seed companies with promises of increased productivity, ease of application and profits. However, with the increase of weed and insect resistance, farmers were finding themselves increasingly dependent on (often global) seed companies, finding it hard to revert to previously available indigenous seeds and having to resort to using ever-larger dosages of pesticides.

Comparing stakeholder opinion

Structured in-depth interviews and an associated electronic survey were conducted with key stakeholders in the three case sites. These included representatives from multinational seed companies, indigenous organisations, women's associations, environmental groups and other NGOs, religious organisations, smallholder farmers, medium- and largeholder producers, social scientists, natural scientists, consumer associations and regulators. Interestingly, bar a few exceptions, all stakeholders across the three cases sites of Brazil, Mexico and India considered the countryside to be in some state of crisis. Representatives from NGO and smallholder associations tended to attribute this crisis as a product of two decades of deregulatory neoliberal policy-making, whereas representatives from the seed companies and from largeholder producers tended to advocate more deregulation and the adoption of innovative technologies as the solution, to make agriculture more competitive internationally and thus help resolve the situation.

Most of the stakeholders interviewed, with the exception of representatives of smallholder farmers and women's associations, were fairly familiar and knowledgeable about debates on GM agriculture. As would be expected, the Mexican stakeholders differentiated between the case of GM maize and other GM crops. Many of the stakeholders, with the exception of representatives from the seed companies and large farmer associations, reproduced a shared set of arguments: that Mexico is the centre of origin of maize, that this represents a collective national responsibility, that current regulatory systems and capacities are not to be trusted to preserve native maize biodiversity, and so on. The representatives from the seed companies and large farmer associations offered a different opinion. For them, GM maize offered significant potential to improve food security and help resolve the crisis in agriculture. They also represented GM agricultural technologies as part of a gradual and continuous path of science working towards agricultural improvement, rather than as a rupture or break with conventional breeding practices as the other stakeholders tended to believe. Stakeholders in India and Brazil reproduced similarly divergent perspectives on GM crops, although there was less differentiation associated with the GM crop in question (i.e. GM soya and GM cotton) compared to other GM crops. Concern was expressed that GM crops create dependency on seed companies, that it could cause problems to human health and the environment and that it could further worsen conditions in rural areas. A minority opinion, largely shared by (some) natural scientists and representatives from seed companies, was that GM crops were a good example of scientific advance that could assist their respective country become more economically competitive and feed their growing populations. Ontological arguments (e.g. that GM crops were wrong, that they were an example of hubris or 'messing with nature') were more common in stakeholder discourse in India and Mexico, less so in Brazil.

The general picture in Brazil was that the public debate on GM crops had receded. This was not the case for Mexico or for India where the debate was perceived as ongoing and live. However, across all sites, the majority of respondents agreed that access to reliable and quality information had been limited and that the public debate, so far, had been unable to resolve underlying problems of agricultural innovation and food security. Generally, stakeholders agreed that there existed a lack of informed debate and a lack of transparency and participation in decision-making processes. For the Mexican stakeholders in particular this was emblematic of wider problems in political culture, as reflected in current and pervasive debates on political corruption.

There was further convergence in the perception of whose voices had been vocal and effective and whose had not. The voices who had been least vocal were perceived to be consumers, smallholder farmers, indigenous groups and (for Mexico and India) the independent neutral scientist (e.g. those not funded by the seed companies). Whereas the voices that had been most vociferous in the debate were perceived to be the seed companies, politicians, government agencies and (for India) NGOs. Interestingly, both in Mexico and India, large-scale farmers felt under-represented, while in India in particular, natural scientists felt that their opinions had not adequately been taken into account. In addition, across India and Brazil (less so in the case of Mexico), there was little support for the view that indigenous and religious groups should have more of a voice in decision-making processes. Generally, participants agreed that decision-making should be guided by independent scientists (for some this included social scientists with expertise on social impacts) while those actors who were felt should be excluded were: scientists with a conflict of interest, corporate actors (who had a vested interest), NGOs (who were commonly viewed as having had a negative influence), churches and religious organisations (who lacked expertise) and, at least for representatives of the seed companies and some natural scientists, consumers and consumer organisations (who lacked relevant knowledge).

Comparing the laboratory ethnographies

Within each case site we undertook ethnographic research in a public or non-profit research laboratory. In Mexico our research took place in the publicly-funded National Laboratory of Genomics for Biodiversity (Langebio), in Guanajuato. In Brazil, our research was undertaken in the state-owned soya research division (CNPSO) of the Brazilian Agriculture Research Company, Embrapa, in Londrina. While in India, our ethnography was carried out in the New Delhi branch of the non-profit organisation, the International Centre for Genetics and Biotechnology (ICGEB). All three were high profile, nationally-significant genomic research laboratories, led by eminent academics and staffed by elite researchers. Nevertheless, all three were suffering to various degrees from a lack of confidence. At Langebio (Mexico), within the Maize Genetics and Genomics group, there was no research being undertaken on the development of GM maize; at CNPSO (Brazil), where earlier pioneering research had been responsible for the expansion and adaptation of the soya bean to the hot, humid and acid climes of the Cerrado biome, the organisation had lost ground to foreign-owned multinational seed companies who now commanded the market of soya bean cultivars in Brazil; while at ICGEB (India), the organisation, while still receiving state funding, had been rendered at the time partially impotent by the 2013 indefinite moratorium by the Indian Supreme Court on GM food crops, including field trials.

All three research laboratories were conducting their research with a strong social mission, developing projects aimed at providing solutions to the pressing problems of the global South, namely feeding a growing population, improving resilience and food security, and developing high yield crops better suited to local conditions. Research projects included the development of new varieties of crops tolerant to herbicides, other varieties breed for increased tolerance to drought and salinity, others with resistance to insects and other fungal and viral diseases, others with delayed ripening varieties aimed at lengthening shelf life, and finally others with improved nutritional qualities.

Most of the researchers interviewed in the laboratories were strongly and unequivocally pro-GM, a position justified for differing reasons. At ICGEB (India), for example, the rhetoric oscillated between the position that emphasised that GM food was safe and the one that argued that GM crops were needed specifically for developing countries, which could not afford non-GM food crops, including organics, and that therefore it was 'the lesser of two evils' when compared with starvation and the over-use of pesticides. At CNPSO (Brazil), researchers tended to view GM crops as offering the potential both to improve food quality and to feed a growing global population. However at Langebio (Mexico), the rhetoric was more variegated. Whereas older and more senior researchers tended to adopt a more avowedly pro-GM stance for all crops, including GM maize, younger and more junior researchers were more nuanced. In relation to GM maize in particular, these researchers tended to distinguish between the introduction of 'foreign' (i.e. non-maize) genes into maize (transgenesis) and the re-working of genetic material within the maize's genome (cisgenesis), and to be more cautious as to whether we have sufficient current understanding of the maize genome to consider its genetic modification.

Ontologically, the researchers tended to deploy a reductionist form of discourse. They tended to see the genetic modification as no different in kind from conventional forms of breeding. Plants considered as an amalgam of genetic material (rather than as a product of social practices) led researchers to believe that there existed apparently limitless possibilities for genetic improvement. Genetic modification was seen as allowing for the indefinite extension of human intervention of nature. Ethical and social responsibilities were defined primarily as ensuring that research conformed to standard norms of research integrity, and that research priorities were frame by the national interest, defined as helping the nation to become more economically competitive, to feed its growing population and to develop its science base. Researchers believed that current varieties of GM crops were safe and that future varieties would be safe so long as regulation continued to be carried out using strict biosafety protocols. The retention of national sovereignty was a key concern across the three research laboratories, with concerns expressed at all levels of the organisation about the widespread adoption of GM seeds from foreign-owned multinationals.

Researchers also tended to adopt a traditional division of academic labour, viewing their responsibility as that of producing reliable knowledge (within the context of nationally-agreed research strategies) with little overt responsibility for how the fruits of their research would be used downstream. The science of GM tended to be represented as essentially producing social goods and thus not in need of external societal shaping. Thus, across both the CNPSO (Brazil) and ICGEB (India) laboratories, there was irritation expressed in the ways in which farmers were applying GM crops whose practices, driven by the apparent desire for short-term profit, were perceived to be creating weed and insect resistance by not following the necessary and relevant management guidelines (e.g. recommended crop rotation practices and the planting of refuges).

Within each of the research laboratories, there was little evidence of a structured and sustained debate with society at large. Lay opinion tended to be dismissed as ill-informed and as overly focused on the negative aspects of the technology. Any existing dialogue with those outside the laboratory was largely restricted to farmers and academic peers. Even in the latter case, human and social scientists were often mistrusted in their scientific credentials. Laboratory scientists did not feel they needed 'to sell' their achievements by convincing the wider public. Rather, according to these scientists, it is up to the market and for individual consumers to decide whether or not to adopt GM crops and foods. The target stakeholder for the research laboratories was viewed as the farmer, not the consumer.

For these reasons we found that there was no clear and deliberate strategy for the research laboratories to communicate to a wider audience of relevant interlocutors, nor was there a developed or collective sense of accountability to those people who will be affected by the technology, even in the absence of whether users have intentionally chosen to adopt and consume GM crops and foods or not. This self-understanding presents considerable difficulties for the development of interdisciplinary research, including the role and remit of the human and social sciences. For the latter, criteria of informed, meaningful and fair participation are often viewed as a necessary pre-condition for the legitimacy of public decisions: technical and scientific ones included. Given that this understanding is not shared by for example laboratory researchers, it is thus not surprising that dialogue across the natural and social sciences remains has been fraught with misconception and tension.

To summarise, notwithstanding the high quality and at times pioneering research being undertaken within each of the three research laboratories, the research culture of the laboratories across the three sites could be described as lacking in 'reflexivity' and 'inclusiveness' – two of the core dimensions of a responsible innovation governance framework as set out in Chapter 1 of this volume (see also Stilgoe *et al*. 2013). With the partial exception of some of the Langebio (Mexico) researchers, the researchers interviewed for the study appeared to lack reflexivity in three regards: first, they appeared to lack the motivation to understand the (legitimate) reasons why GM crops have become controversial in each country, preferring instead to regard such resistance as ill-informed, ideological and ignorant. Second, they further lacked the motivation or encouragement to work with other disciplines from the human and social sciences, including those could help provide sociologically-informed understandings of the controversy and of (latent) public concerns, preferring instead to view such disciplines as lacking in relevance and/or competence. And third, even though each of the laboratories carried out their research within a clear and strategic national mission, what constituted the national public interest tended to be taken as a given, and where there were few forums for scientists to deliberate with other actors as to whether their framings aligned with wider social values and needs. The research culture of the laboratories were similarly lacking in inclusiveness. Researchers did little to listen to, understand, or engage with wider social actors or views – and their often divergent framings of the issues – and had not developed a collective sense of responsibility for the outcomes of their research as they would be used in practice. These two dimensions (inclusiveness and reflexivity) will be examined further in the final chapter of the book (Chapter 17, this volume) when we set out a proposed framework for the responsible innovation of GM crop technologies.

Comparing the public research

A key element of our research involved the attempt to understand lay public attitudes to GM crops and foods across Mexico, Brazil and India. As evidenced, one striking feature of the debate on GM crops and foods across all three countries is the lack of an informed and comprehensive public debate. In addition, except from a few opinion surveys and a couple of ad hoc public engagement exercises, little knowledge exists on what ordinary people actually think about the subject. In our research we developed a methodology designed specifically to open up conversations with lay publics in contexts where they may (or may not) be familiar with the technology. This methodology was developed first in the UK in the 1990s to help understand the factors shaping public perceptions to GM foods and crops (Grove-White *et al*. 1997), and subsequently amended and deployed to explore public responses to GM animals (Macnaghten 2004), nanotechnology (Macnaghten 2010) and solar radiation management (Macnaghten and Szerszynski 2013). It involves developing conversations on the social context through which attitudes are expected to form, followed by an introduction of the technology, discussion of current societal and scientific debates, and deliberation on the responsibilities and roles of different actors in the debate, including their own.

The first point of comparison relates to the different underlying cultures of food emerging in and across the three national contexts. In Mexico, we found a heightened and shared appreciation of maize products and cooking, as a part of Mexican identity and as a medium in the maintenance of diverse social practices. Such an appeal to tradition provided a foundation for structuring subsequent responses to GM foods, and to GM maize in particular. In Brazil, by contrast, we witnessed a different dynamic. We found evidence of a fairly intense concern with the industrialisation of foods, and, for at least the better off, a desire to consume foods as organic and local as possible as a response. This unease with the direction in which food production was heading provided a different kind of foundation for structuring subsequent responses to GM foods.

A second point concerns the care and attention with which our participants were able to engage with the issues presented by GM foods and crops. At the start of the discussions, most of our participants were unfamiliar with the technology and how it was being applied across GM crops and foods. However, as the discussion progressed people's thinking matured and hardened as people began to consider questions of trust, governance and the responsibility of different actors. In this respect, the methodology worked to good effect. It enabled people to discuss the technology and to develop views.

The third point concerns the overall perception and tone of public responses to GM crops. With the exception of a few members of the student group in India (students who were studying biology and who were enthusiastic advocates of biotechnology), there was little expressed public enthusiasm for GM foods and crops, which were considered, more or less across the board, as an intrinsically unsettling technology. Reasons for this were various. For many of the Brazilian participants, when introduced to the topic of GM crops and foods, we found little knowledge or awareness and genuine surprise about the extent of its adoption. People thus adopted negative views partly because they felt they had not been consulted and inadequately informed. When coupled with the uncertainties of outstanding health impacts, people responded viscerally and negatively. Similarly, for the Mexican participants, the perception that the food companies were opposed to the labelling of GM foods, generated suspicion and outrage that their 'right to know' was being usurped.

Other factors shaping people's negative attitudes to GM crops and foods included: that the case for why the technology was needed had not been demonstrated (Mexico), that current cultures of science did not have the proven capacity or integrity to predict future harms (Mexico), that regulatory agencies were not to be trusted (Mexico), that the good intentions of the seed companies were not to be trusted (Mexico), that the application of agriculture GM technologies were benefitting the large producer at the expense of the family farmer (Brazil and Mexico), that they saw few consumer benefits (Brazil), that those promoting the technology (scientists, government actors and seed companies) were 'manipulating' the debate to suit their own interests (Brazil), and that the promise that GM crops would promote sustainability was seen as a contradiction in terms (India). The claim that 'GM crops could help feed the world' was viewed by most participants as implausible, across all three case sites, given that the political economy surrounding (at least first generation) GM crops was seen as aligned to capital and intensification.

However, there were some relevant specificities in the group discussions. For the Mexican participants (as this research shows fairly conclusively) there was increased sensitivity with GM maize whose promotion – by seed companies and parts of government – was seen as a symbol for wider unease, namely, the apparent collusion between the political class and large corporations at the expense of the wider public interest. For some of our Indian participants, particularly from rural areas, the actual gene used in the genetic modification of plants was seen as relevant. Insertion of animal genes into plants was seen generally as less acceptable as this would transgress religious taboos. Finally, there is the question of governance. Many of the participants called for government to take more active and proactive responsibility in governing for the public interest. Governments, participants suggested, should be responsible for clear and transparent regulation, for assuring safety, for raising consciousness and for promoting the public interest. Public universities and educational establishments were also accorded a priority role in fostering the creation of critical and participative citizens. Interestingly, institutions who did not command trust, and whose motivations were seen as doubtful included NGOs for many of the Brazilian participants (less so, for the Mexican and Indian participants).

Comparing the deliberative workshops

At the close of each fieldwork session our local teams, under the guidance of the Durham research team, organised local deliberative workshops with stakeholders. The workshops had two functions: to elicit reflection and deliberation on the field research, and develop (if possible) a set of consensual priorities through small breakout group work for how to best progress the debate on GM crops. The workshops were well attended, spectacularly so in Mexico, and included, among others, representatives from government departments, regulatory bodies, seed companies, civil society organisations, women's organisations, smallholder farmers' and medium and large producers associations, organisations, indigenous organisations, environmental and consumer groups, as well as natural and social scientists.

The workshops generated rich and varied debate. By and large, participants welcomed the debate as a valuable, and atypical, contribution. Bar a few disagreements (between participants with avowedly pro– and anti– positions) there was a surprising degree of consensus and common purpose, aided by the deliberative methodology and the non-confrontational style adopted by the workshop organisers. Excluding a few natural scientists and representatives from seed companies, who argued that the debate had been settled in favour of GM crops, the majority of participants shared the view on the need to open a new cycle of debate on the issue. For the Indian breakout groups, the agreed priority areas were to develop novel forms of public consultation, to develop constructive and critical public engagement, to widen and deepen the debate and to listen to a wider range of stakeholders. Similarly, for the Mexican groups, the majority view was to advocate the need for a new set of transparent, inclusive and democratic debates. While, the Brazilian participants too called for concerted action to communicate reliable information, and for proper channels of citizen participation in strategic decisions including the organisation of deliberative policy conferences. Such calls thus spoke of the shared perception, commonplace across the three national contexts, that the debate so far on GM crops had been far from inclusive, transparent or participatory. In the Mexican context in particular, the voice of smallholder farmers was perceived to have been dramatically absent.

A second priority area, common across the three national workshops, was the call for education and the development of critical citizens. For the Brazilian participants, the public universities were accorded a special role. The lack of quality, unbiased information was perceived as a significant and ongoing barrier with media outlets commonly perceived as untrustworthy, and for many, as biased and self-interested. Public universities, public scientists, teachers, researchers and (some) journalists however, were trusted, alongside citizen and consumers' groups, and a priority area was for these actors to fulfil their responsibility of providing impartial information and in creating critical citizens. The government too, was accorded a role both in promoting informed debate through public events and in providing participatory forums for public deliberation. Again, the implication was that these bodies were insufficiently fulfilling their obligations, to date.

A third priority was for initiatives that seek to bridge the gap between scientific practices and imaginaries in the laboratory and in situ practice in the field. In the Indian workshop in particular, participants spoke of the problems associated with agricultural labouring practices not confirming to agreed guidelines and standards, such as labourers not using gloves and masks when applying pesticides. Again, the proposal was for government to develop both a more rigorous regulatory framework at the national level, and at the local level, to develop a stronger monitoring and implementation capability. A fourth and final priority area, again prominent in the Indian workshop, was the call for GM research institutions to develop greater socio-cultural sensitivity: to develop life science research that better responds to India's strategic needs as considered by local actors, to both understand and accommodate different framings of the issue, including religious sensitivities, and to do so in a way that is accountable, transparent and responsive.

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PART II

Commentaries on governing GM crops

In Part II we open up the debate on the governance of GM crops through a set of commentaries from a number of pre-eminent scholars and practitioners across the crop science, policy studies, science and technology studies and anthropology communities. The commentators were all participants in a policy workshop organised at the Royal Society in June 2014, designed to draw lessons from the GMFuturos research, and to explore the future of GM policy in the UK and Europe within a responsible innovation framework.

The plant scientist Ian Crute is our first commentator. In Chapter 6, Crute reflects on the GMFuturos study as a valuable attempt to side-line the worn-out debate on the 'risks' of GMOs, through its focus on the impacts of GM crops on farmers' *in situ* livelihoods and on wider societal values. Crute situates the study historically, in the context of a long history of controversies that have surrounded the genetic improvement of crops. He then argues that if we are to meet the grand challenge of feeding a future world of at least 9 billion people, and to do so securely, sustainably and equitably, we will need to embrace radical agricultural innovation and to move beyond existing configurations of the GM crop debate, which he describes as 'unhelpful caricatures'.

In Chapter 7, science policy researcher Adrian Ely points to the value of the GMFuturos study as providing much-needed empirical data on 'local' perspectives on GM crops in three global 'rising power' contexts – Mexico, Brazil and India. He compares these cases with that of China, focusing on the particular governance and political contexts in which China is responding to the challenge of GM crops. Ely exposes clear parallels, namely, that China has not offered a situation of 'authoritative governance', and that GM crops continue to be constituted by diverse actors in China as a symbol of wider struggle.

In Chapter 8, development studies researcher Dominic Glover situates the GMFuturos research as a necessary antidote to the narrative that presents the adoption of GM crops in 'rising power' settings as an unequivocal success story. He highlights how the study counters this narrative: through the finding that both growers and consumers feel ill-informed about the technology and excluded from decision-making processes; that smallholder farmers evince little trust in the technical advisors of the extension services; and that the issues at stake reflect conflicting interests and competing visions that are intrinsically difficult to reconcile. He proposes the idea of 'stewardship' as an integral element of a future responsible innovation framework.

In Chapter 9, anthropologist Penny Harvey develops a non-reductionist account of GM crop technologies paying particular attention to the multiple ways in which GM crops are infused with particular values, symbolic resonances, aspirations and ways of life. She uses the concept of the assemblage, and an approach that focuses on people's practical activities, to help understand the GM crop controversy, and the various ways in which GM crops cause problems in people's lived worlds. She identifies how GM controversies create publics in a recursive process, that both replay old histories and that stimulate future imaginaries.

In Chapter 10, science and technology studies (STS) scholar Les Levidow contextualises the GMFuturos study – and in particular its analysis of the GM crop controversy as a symbol in the struggle against unwanted forms of globalisation – within a long-standing European political agenda of neoliberal policymaking. Drawing on long-standing historical analysis, Levidow demonstrates how a biotechnological vision of further industrialising European agriculture was promoted as an overall solution to the problem of European competitiveness. Through various policy and legislative frameworks, these institutional commitments foreclosed alternative European futures, thus provoking conflicts over democratic accountability. From this analysis, Levidow draws lessons on the paramount need to contextualise public responses within their political-economic contexts.

In Chapter 11, plant scientist Keith Lindsey seeks to contextualise the science of genetic modification in a broad evolutionary context and within a biological view of the nature of life. He sets out research on the molecular biology of organisms, which demonstrates how similar genes are between different forms of life, and which has led biologists to take the view that exchanging genes between organisms is not so unusual a phenomenon. He derives from this perspective a critique of the current European regulatory system on GM crops as not fit for purpose, arguing that a broader problem-based system is a precondition for responding to the world's food security challenges.

In Chapter 12, physicist and science/theology writer Tom McLeish reflects on the role of theology as offering narrative resources to reconfigure the governance debate on GM crops, and to move beyond the current polemic. Using the 'ancient wisdom' literature as a resource, and drawing on a detailed interpretation of the Book of Job, McLeish develops a theology of technology that speaks to an ethics of human responsibility and a theology that centralises and prioritises the wellbeing of the world before the wealth of human beings. Such narrative reframing is positioned as a response to the tragic tone that informed current responses to GM crop technologies, as evidenced in the GMFuturos study.

In Chapter 13, theologian and ethicist Michael Northcott contextualises the findings of the GMFuturos study within a broader narrative of the disconnect between agricultural science and everyday food practices. What crop scientists commonly miss, he argues, is the relationality that exists between people and land, and between culture and agriculture. Using the TV series *Breaking Bad* as a metaphor for GM crops, and the ancient Greek idea of *poïesis* as a resource, Northcott points to practices involved in the making of food as a source of goodness, truth, beauty and freedom, and as a response to the gradual neoliberal collectivisation of agriculture by private corporations.

In Chapter 14, risk governance specialist Judith Petts locates the GMFuturos study within two decades of research on risk perceptions. She finds a number of convergences that include the power of context, the threat to fundamental values in determining public responses to risk and the observation that negative responses are more often driven by concerns about 'mucking around with nature' and inadequate controls, than with potential risks to the environment and health. She reflects further on the lessons for UK policymaking, pointing to still-prevalent problems of political culture, the need for longitudinal studies and the potentials for emerging policy frameworks of responsible innovation.

In Chapter 15, Rajeswari Raina argues that there are institutional rigidities in the Indian agricultural science and technology (S&T) system that militate against the possibility of more responsive and deliberative alternatives. Notwithstanding widespread criticism, replicated in the GMFuturos study, the Indian S&T system continues to reproduce an industrial model and approach to agriculture which emphasises increasing yields delivered through the supply of inputs in a centrally controlled linear mode. Such institutional rigidities help explain the historical lack of participation and transparency in decision-making on GM crops and the inability of the established scientific and political leadership to engage meaningfully with alternative pathways to sustainability.

In Chapter 16, anthropologist Bob Simpson reflects on the use of focus groups as deployed in the GMFuturos study. Although admittedly not a great fan, he recognises the value of the method as helping open up new kinds of debate, deliberation and participation. Using the notion of unknown unknowns, he develops a vocabulary for the ways in which GM crops threaten people's ontological security with potentially corrosive consequences for human flourishing and livelihoods. He adds to the analysis developed in the study through a focus on the power of economic interests to confound the things that make the unknown accessible, thereby exacerbating the unknown unknowns.

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THE ROUTE TO FOOD SECURITY IS NOT THROUGH GLORIFICATION OF THE RURAL IDYLL AND DEMONISATION OF GLOBAL TRADE (OR VICE VERSA)

Commentary by Ian Crute

The report of work conducted within the project entitled *A new approach to governing GM crops: global lessons from the rising powers* (supported by the John Templeton Foundation; Macnaghten *et al.* 2014, hereafter referred to as 'the report') was 'new' in one key respect. The report purposely side-lines the worn-out debate about crop genetic engineering technology and its purported consumer and environmental risks. For a crop scientist who has been engaged in debates about GM crops for over 20 years, this is laudable and genuinely widens the scope, breadth and value of the study. The work, which was conducted in countries with rapidly developing economies (India, Brazil and Mexico), primarily examined the use of biotechnology in crop genetic improvement as a surrogate for, or 'symbol' of, commercial innovation and the globalisation of agriculture.

Framing a debate about technology and its uptake in terms of impacts on people's livelihoods, societal values and the sanctity of traditions is certainly likely to be more enlightening and rewarding than one that demands a degree of specialist technical knowledge residing with few apart from bioscience professionals. This said, I am impelled to state that there were no opinions, arguments or perspectives presented in this report that I had not heard or seen advanced previously albeit without the backing provided by the impressive scale of first-hand evidence gathered in this study.

Before continuing, let me record my own position on the role of biotechnology in crop genetic improvement based on my career experience. I consider crop genetic improvement (for yield, quality, disease resistance, nutritional attributes and so on) to be vital for future human well-being (as it has demonstrably been in the past). I consider the conservation of genetic diversity of crops and crop relatives (both *in situ* and in gene-banks) to be vitally important. I believe in deploying all available tools and technologies necessary to achieve, by the most effective and efficient means, the specific improved crop performance that is being sought. I take the view that regulation of technology associated with plant breeding (as distinct from the novelty of any derived product) is unnecessary and that the excessive burden of regulatory cost represents a real risk. Through costly regulation there is a very real prospect that the endeavour of crop improvement will become the exclusive province of large corporations; no society will be well-served by the development of monopolies. As with other creative pursuits, I also consider it appropriate that the creator of a new crop variety should be able legally to protect their product in the market place and obtain a royalty on its use (through 'plant breeders' rights') including the use of self-saved seed. However, I oppose the patenting of genes or genetic improvement technologies. This approach to protection of intellectual property can be detrimental to progress since it denies the use of a successful variety by others as a valuable parent in subsequent crosses directed towards further incremental improvement. In general, I view patenting activity in crop science (in contrast to chemical discovery for example) to be an impediment to progress rather than the stimulus that others suggest. Moving beyond the specifics of crop improvement, anything that delivers the prospect of a narrower gulf between the rich and the poor must be welcomed; and for me this includes the freedom to grow and sell whatever there is a market for with as little restriction as possible within a framework of safeguards for consumers and detriment to public goods.

In the final analysis it will be for markets (small or large, national or international) to decide if crops and crop products produced through the application of modern biotechnology will be traded; and it will be for governments (national and local) and transnational governmental organisations to decide how liberal or regulated their markets will be and the extent to which interventions and subsidies will be used to achieve political objectives. The extent to which seed companies, farmers, food manufacturers and retailers or consumers can influence these decisions is determined by their political influence either through the ballot box or other means (such as through mass media). For example, seed companies and farmers in Europe have singularly failed to match the political influence of NGOs, consumers and retailers with regard to creating a receptive regulatory regime for the cultivation of GM crops. As is evident from the report, the priorities for national governments can differ considerably and some are more readily influenced than others by popular opinion on the one hand or macroeconomics and long-range development agendas on the other.

Against this background, there is rather little disagreement that a future world of at least 9 billion people urgently requires a route map leading to functional systems that will deliver to a predominantly urban population essential food and other products from land and water in sufficient quantity, securely, sustainably and equitably. The debate to be had, hopefully productively and with open minds, is all about the route by which sustainable, secure and equitable systems of production and distribution will be achieved. In this regard, support for GM has become emblematic of a route that emphasises government-aided, commercial investment in protected intellectual property with applications in the large, profitable, global markets represented by major traded commodities and destined to annihilate small local producers and markets. Likewise, hostility to GM has become emblematic of a quite different route envisaged by those who see a future where agriculture remains predominantly a local enterprise founded on traditional knowledge and dependent on government subsidy. These two scenarios are, of course, unhelpful caricatures of unrealistic endpoints. Nevertheless, it is helpful to explore the origins of such polarised positions that are so clearly manifested in the debate about GM crops and crop products. This is the report's most valuable contribution; it seeks to shed light on the non-scientific influences (social, cultural, historical, political, ethical and even religious) that impede progress towards the accommodation in the twenty-first century of a pluralistic approach to innovation in agricultural systems that broadly characterised remarkable development during the twentieth century.

During the last century the widespread adoption of a raft of new (but now 'traditional') technologies enabled a 250 per cent increase in the global population (from 1.7 to 6.0 billion) to be fed from only a 40 per cent increase in the area of cultivated land (from 1 to 1.8 billion hectares). The so-called 'agricultural revolution' of the latter half of the nineteenth century fully ran its course during the first half of the twentieth century to be supplemented by the so-called 'Green Revolution' that brought about the spectacular increases in productivity that characterised the latter half of the last century (120 per cent increase in population; only a 15 per cent increase in cultivated land; and 27 per cent increase in kcal per person per day). Regrettably, despite these advances, and for reasons substantially unconnected to the potential for increased production, there remain hundreds of millions of people (14 per cent of the global population) who are undernourished. The vast majority (95 per cent) of these hungry people inhabit rural areas where, without the necessary investments in established technologies, population often exceeds the productive capacity of land that previously supported fewer people. These points are well amplified in the UK 2011 Foresight report *The Future of Food and Farming* and its associated literature (Foresight 2011).

It is worth emphasising that the report addresses just a single component (i.e. seeds or other planting material) of the many inputs that go into making a productive, sustainable and resilient agricultural system; but this planting material is a particularly critical component in terms of the yield, quality, integrity and health of the derived crop (whether annual or perennial). For these reasons, planting material (alongside early machines) was among the first component of the system to be 'commercialised'; the first European seed company, Vilmorin, which is still trading today, was founded in 1743, and the first in the US some 40 years later. The scientific foundation for the genetic improvement of crops came much later with Sir Roland Biffin's work on wheat in Cambridge early in the twentieth century. This was stimulated by the rediscovery of Mendel's studies on inheritance. Biffin's work led, in the UK, to the creation of the government-funded Plant Breeding Institute that was sold to Unilever in the late 1980s, and thence to Monsanto in 1998 (who moved their research out of Europe in 2003). This century-long saga reflects a continuing global trend driven in large part by the source of necessary investment: public support in the national interest giving way to privatisation in a regional context and leading to multinational acquisition with global outreach. However, it is necessary to note that in many parts of the world where a sophisticated commercial seed production and supply industry is absent, seeds themselves are still traded as they have been for millennia; they are just like any other valued commodity.

Over the decades, and well before GM was even dreamed of, plant breeding has not been without its 'political' controversies (covered in Noel Kingsbury's book *Hybrid: the history and science of plant breeding*). Most serious was the Stalinist support for Lysenko's politically convenient Lamarckian approach to plant breeding in the 1940s. This was adopted in strong opposition against work guided by the Mendelian principles of inheritance which were deemed politically incorrect by the communist regime. The result was the persecution, demonisation and death of Nikolai Vavilov and other Soviet plant breeders. Vavilov was a pioneer of biodiversity conservation in the context of crop improvement and was posthumously rehabilitated during the Khrushchev era.

In the 1960s, several countries implemented laws protecting plant breeders' rights, which enabled plant breeders to protect their varieties and collect royalties from use of seeds or plants. This was not universally popular since it had not been uncommon practice for some companies during prior decades simply to obtain, grow and rename varieties from competitor companies; the plethora of named varieties, offered to growers, concealed enormous synonymy. Today, in Europe, there is continuing opposition from some groups to the illegality of trading seeds that are not approved as 'Distinct, Uniform and Stable' (DUS) and registered on National Lists or the EU Common Catalogue.

Despite their dominance in many crops, the development and use of F1 hybrid varieties has not been without its critics and problems. The positive stimulus that hybrid seed production gave to innovative crop improvement is captured in the early writings of Edward East, one of the pioneers of hybrid maize. In 1919 he wrote (with Donald Jones) of F1 hybrids:

> it is the first time in agricultural history that a seedsman is enabled to gain the full benefit for a desirable origination of his own … A man who originates devices to open our boxes of shoe polish is able to patent his product and gain full reward for his inventiveness. The man who originates a new plant, which may be of incalculable benefit to the whole country, gets nothing … as the plants can be propagated by anyone. The utilization of first generation hybrids enables the originator to keep the parental types and give out only the crossed seeds, which are less valuable for continued propagation.
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> *(East and Jones 1919: 224)*

This was, in effect, equivalent to a patent (without the need for a patent attorney) and for this reason alone there were, and still are, opposite opinions about the benefits deriving to growers, particularly in developing countries when self-saved seed underpins traditional production systems. A further hypothetical risk of agriculture dominated by genetically uniform hybrids became reality in the US in the period 1968–1971 when huge yield losses in the maize crop (with major economic impact) occurred. This resulted from an epidemic of a new disease (Southern Corn Leaf Blight) to which most varieties being grown proved highly susceptible (Ullstrup 1972). The circumstance originated from the widespread use of a single source of cytoplasmic male sterility (referred to as cms-T) to produce hybrid seed.

This short tour through some historical controversies associated with technical and regulatory innovations connected to crop genetic improvement just serves to illustrate a point. There really is little that is entirely novel about the opposition that introduction of GM crop varieties has provoked among certain constituencies in particular places for reasons other than those founded in science. This set of comments has been stimulated by a report which clearly informs us that we must respect and respond to the differential values that countries and peoples place on conservation of cultures, traditions, landscapes and societal structures. At the same time there must be recognition that there are often costs to be borne elsewhere in economies from such conservation; value judgements are necessary and value means costs. Equally however, there are messages about the need to champion the freedom to educate, innovate and make beneficial change as well as to challenge the propagation of misguided fears and factual inaccuracy.

It is as inappropriate for European institutions to attempt to direct the agricultural development of countries such as India, Mexico and Brazil as it is for these countries to press their views on the way others choose to produce and trade agricultural products. Case studies relating to Africa in the recently published report from EASAC are testament to this (EASAC 2013). Nevertheless, rational analysis and debate founded on sound evidence and views about how such attributes as: resilience, sustainability, equitability, sufficiency and security should be defined and measured are hugely important. Different geographical and cultural environments will demand different means towards similar ends and there will always be the need for trade-offs.

I am much persuaded by the utility of the concepts behind the phrase 'sustainable intensification' (Royal Society 2009). The ideas emerged from practical work with smallholder farmers in Africa but they capture some unifying principles which address the primary challenges facing all agricultural production systems. The concept responds to data and rejects dogma; it is inclusive not exclusive of approach; it is driven by outcomes and not the means to be used; and it emphasises 'both/and' rather than 'either/or'. The objective is simultaneously to raise productivity, increase resource-use efficiency and reduce negative environmental impacts. As a scientist trained to erect hypotheses and then search for data to invalidate them, I am on the look-out for data to invalidate the following hypothesis: '*Producing as efficiently as possible on the smallest footprint of land capable of delivering, but not exceeding, the requirements of markets (or dependents) is the most profitable and environmentally benign way to farm.*' From my perspective we should ensure farmers and growers are never denied access to 'all the tools in the box' and know how best to use them. One thing I think we can conclude from the report, and much else that preceded it, is that glorification of the rural idyll and demonisation of global trade (or vice versa) is not the route by which the food security of families, societies or nations will be forthcoming.

Author biography

Ian Crute is a plant scientist who has enjoyed 40 years of employment exclusively in publicly funded organisations, most recently as Chief Scientist of the Agriculture and Horticulture Development Board. His specialism is in crop diseases (particularly of vegetables and fruit) and their integrated management through genetic improvement of plant resistance and deployment of fungicides. He has never created a GM plant nor been directly involved in projects to produce GM crops; nor has he ever sought to benefit from protected intellectual property. He has often worked in collaboration with companies, mostly for mutual benefit and without financial arrangements. The anticipated beneficiaries from his work are farmers and growers, but the development, registration, seed production and marketing of an improved crop variety is a necessary step for his work to have had practical impact.

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7

LESSONS FROM CHINA'S GM CONTROVERSY

Commentary by Adrian Ely

The insights offered by the GMFuturos project are refreshing for many of us who have been watching political debates unfold across the so-called 'rising powers' over more than a decade, but in the absence of clear empirical data on the perspectives of citizens in these diverse nations. My commentary focuses on another of the 'rising powers', China, and provides a very brief account of what we know about policies, public attitudes and decision-making on genetically modified (GM) food and crops in that strategically important country. Taking into account the specificities of China's dynamic governance context, I then reflect on some of the challenges of responding to the 'institutional void' highlighted by the authors at the international level.

China provides an important comparison to the other 'rising powers' discussed in this volume because of its scale, its growing leadership in agricultural science and technology and the particular challenges it has faced around the commercialisation of GM food. The country has invested hundreds of millions of US dollars in agricultural biotechnology research since it released its first transgenic crop – an insect-resistant tobacco – in the early 1990s. It is currently the world's sixth-ranked country, with 4.2 million hectares being cultivated with GM crops, almost entirely *Bt* cotton (James 2013). The regulatory environment in China is complex, and the precise process leading to the cultivation of new varieties remains relatively obscure and subject to an array of political and technocratic factors. This limited (although in many ways improving) transparency is an important feature underlying public concerns in China. On paper, China's regulatory arrangements are quite comprehensive, having been developed through a series of laws and regulations introduced over a period of more than two decades (Marchant *et al.* 2002; Lightbourne 2006).

As in many jurisdictions, there have been internal struggles for control over this emerging area. The Ministry of Agriculture has traditionally been China's dominant institution for crop biosafety regulation and has also been responsible for supporting the development of China's agricultural biotechnology sector. The ministry has, since 1997, housed the National Genetically Modified Organisms (GMO) Biosafety Committee and it was reported to have resisted calls from the Environmental Protection Agency (now the Ministry of Environmental Protection) for a new Biosafety Law following China's ratification of the Cartagena Protocol in 2005 (Keeley 2006). In making their decisions on GM approvals, Ministry of Agriculture representatives are reportedly joined by those from the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Commerce, the Ministry of Health, the General Administraton of Quality Supervision, Inspection and Quarantine and the State Environmental Protection Agency (*ibid*.).

GM *Bt* cotton has been cultivated in the country for more than a decade, and although regulatory processes have been far from straightforward (Van Zwanenberg *et al*. 2011), public objections have been relatively few. Instead, the country's diverse citizen concerns are better illustrated by the ongoing debates and fierce political controversy surrounding transgenic rice. In many ways these mirror the GM Futuros findings on maize in Mexico where concerns were particularly sharp due to the cultural resonance of the crop. At the same time, the importance of rice for the country's food security cannot be overstated.

As well as a focus on self-sufficiency (which China has currently reached for rice), China's food security approach (as illustrated by the twelfth five year plan) gives priority to innovation in agricultural technology. The country has vigorously supported public R&D and innovation in firms linked to public research institutions. Two transgenic *Bt* rice varieties produced by researchers from such a group at Huazhong Agricultural University in Wuhan were given biosafety certificates in 2009, paving the way for the crop's cultivation. However, four years later, when the certificates elapsed, they were not renewed, prompting widespread speculation of a shift in policy. In the interim, the government did not acknowledge any widespread cultivation of the crop, and vowed to punish severely its commercialisation (Xinhua 2014). Licences for experimental use were eventually (re-)issued in December 2014 (Niu and Stanway 2015).

Official justifications for delaying approval for commercialisation (such as demonstrated health or environmental risks) appear to be absent from the public record, and the reasons behind the non-renewal of the biosafety certificates are also unclear. Before the safety certificates were issued, researchers suggested that food labelling was not yet a contentious issue and that – at least in the urban East – if the crop was commercialised it would have been unlikely to have met much public resistance in China (Huang *et al*. 2006). Since then, government scientists have pointed to the lack of consumer acceptance as a reason for delaying final approval (Niu and Stanway 2013). 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). In September 2014, the Ministry of Agriculture was reported to have cited 'low public acceptance' as the reason for delaying approval for imports of Syngenta's MIR162 soya bean, marking a shift from claims of 'insufficient data' that had obstructed imports since November 2013 (Patton and Pullin 2014).

As with the GMFuturos cases, on both environment and human safety accounts, the country cannot realistically claim a situation of 'authoritative governance'. Public and private standards (for example on organic food) are questioned regularly in the media and environmental regulation (for example on chemical plants such as paraxylene, also known as PX, in Dalian) have sparked some of the most vigorous citizen protests of recent years (Ansfield 2013). Citizen concerns over food safety have been exacerbated since the Sanlu milk scandal in 2008, and subsequent scares around poisoned meat and heavy metal-contamination in vegetables, alongside low levels of public trust in the regulatory system, are important underpinning factors in China's debate on GM crops and foods (Ely *et al.* 2014a). An unapproved transgenic variety known as Bt63 was first reported in food in Beijing in 2006 and US trials on 'golden rice' in 2012 were found to have been implemented without the appropriate ethical review, further stoking public controversy.

At the same time (as found in other cases in the GMFuturos project), GM has also been claimed by various factions in China's complex (and opaque) political arena as a symbol of wider struggle – primarily of a (rising) China vs an imperialist USA, with a multitude of variations on this theme (Cao 2014). Neo-Maoist writers in China's 'New Left' have adopted a particularly critical view towards GMOs in general, while supporters of continuing economic liberalisation focus on China's global competitiveness in this strategic emerging sector (discussed in more detail in Ely *et al.* 2014a). These diverse concerns have recently become a feature of (especially online) media debate and are fuelling wider public mobilisation. Activists have written open letters to the government claiming that 'China is being exploited by agribusinesses' (Stone 2011) and Peng Guangqian, deputy secretary-general of the National Security Policy Committee, has likened GM food to 'a new kind of opium being forced upon China by Western companies' (Stanway and Niu 2013). State media has – possibly for the first time in the history of China's governance of science and technology – become a forum for (often confrontational) public debate. Since 2013 China has witnessed an ongoing 'celebrity feud' between two prominent public figures: between Fang Zhouzi, a science writer, and Cui Yongyuan, a TV presenter who had travelled to the USA to make a film about concerns over GMOs (Zhang 2013).

With the exception of a small number of studies (Ho *et al.* 2006; Huang *et al.* 2006), concrete data on citizen attitudes in China and detailed studies of the public debate are largely unavailable in the international literature. It is difficult to ascertain whether such findings are being evaluated by government, and how, if at all, they interact with formal decision-making procedures. While there may not be a complete 'institutional void' in terms of the procedures through which China has traditionally made decisions about science and technology (which, through the party structure, do attempt to take into account public opinion), such a void certainly exists in terms of open public participation. Calls for public engagement around GM crops in China are not new (Jia 2010); however they have intensified in recent years and months and the changing role of (especially social) media in China's environmental governance in particular (Geall 2013; Ely and Tyfield 2013) has meant that public participation is becoming a phenomenon that the government is having to respond to.

Importantly, any institutional innovations in the Chinese context would need to take into account the very different food security challenges faced by the country, but also the hugely divergent governance context in which citizens might be involved. Simplistic suggestions of further opening up and supporting public debate in China are often based on Western notions of democracy that are not likely to be taken up wholesale in a country where – in government circles at least – a technocratic approach to policy-making and a 'deficit model' perspective on communicating around science and technology is still prominent (Jia and Lu 2014). It may be that improved anticipation, inclusion, reflexivity and responsiveness (the AIRR framework of responsible innovation as described in chapters 1 and 5 of this volume) are possible elements in the gradual reshaping of China's systems of science and technology governance: however it is unlikely that the resulting institutional innovations will resemble those emerging in the West. China is increasingly opening up to external inputs, for example from academics, in its national planning processes. In addition it has experimented with consulting the public on draft regulations, for example around health policy. Spaces for meaningful public participation in GM decision-making in China are likely to evolve alongside these kinds of ongoing political reforms and to articulate with enduring components of the Chinese system of governance. Indeed, all aspects of the AIRR framework are likely to be operationalised in very different ways, based on the historically embedded governance contexts of specific national jurisdictions.

This leads me on to perhaps the most complex of challenges, as I see it, of how to involve citizens of different countries in technology assessment processes and decisions at the international level. Beyond enabling individual, isolated experiments in public engagement (which already exist) lies the challenge of developing parallel, ongoing processes that 'talk to each other' across different geographical and socio-political contexts. Previous work by my colleagues and I on international technology assessment (Ely *et al.* 2011) pointed to the trade-offs between adopting a rigid framework that would enable direct comparison/integration of technology assessment across multiple contexts, and the need to remain flexible to local problem framings, perspectives and governance contexts. We pointed to the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) as an example of an internationally organised, networked attempt to broaden out the inputs to technology assessment, that highlighted the multi-functionality of agriculture and the impossibility of reaching consensus on contentious issues – such as the potential contribution of GM crops in agricultural sustainability – at a global level (Ely *et al.* 2014b). Linking up smaller-scale, bottom-up technology assessment exercises might be an alternative way to create space for yet more diverse voices, but problems with articulating their lessons in a common framework act as a barrier to mutual learning. In addition, they are of limited applicability in societies such as China where civil society exercises of this sort are less established.

International, networked institutions for citizen involvement, however, also need a responsive political system that can interpret their outputs and take them forward in policy, regulation and governance. The IAASTD, despite being supported by major intergovernmental organisations, was not ratified by those same organisations and thus – while it may have altered debates at the international level – cannot be said to have had direct impacts on national policy. Without a responsive political system that reaches across national jurisdictions, the 'institutional void' that is highlighted at national levels in the GMFuturos project (for Brazil, Mexico and India) will continue to act as an insurmountable barrier to meaningful citizen involvement at the international level.

Author biography

Adrian Ely is a Senior Lecturer at the Science Policy Research Unit (SPRU) and Deputy Director at the ESRC STEPS Centre, where he also acts as Head of Impact and Engagement. He has participated in research on the regulation and governance of agricultural biotechnology since 2001, adopting a comparative approach to the analysis of biosafety policy and decision-making in Kenya, the USA, numerous European states and at the international level. Since 2007 he has also undertaken research in China, publishing the book *Regulating technology: international harmonization and local realities* with British and Chinese co-authors (Van Zwanenberg *et al*. 2011). He is currently co-investigator on an ESRC project entitled Low Carbon Innovation in China: Prospects, Politics and Practice, where he leads the food and agriculture research package, investigating the role of transgenic technologies in the country's search for environmentally sustainable food security. These specific research areas combine with an overarching interest in international technology assessment and governance (Ely *et al*. 2014b).

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8

PUBLIC PARTICIPATION, ACCOUNTABILITY AND THE STEWARDSHIP OF TRANSGENIC CROPS

Commentary by Dominic Glover

Anyone who has kept half an eye on public debates and media reporting about transgenic crop issues over the last decade may well have received the impression that farmers and publics in several 'developing' countries have embraced GM crops and foods. After all, transgenic crops such as soya beans, cotton and maize are being grown by numerous farmers, including smallholder cultivators, in populous low- and middle-income nations such as China, India, Brazil, South Africa and Pakistan, and a handful of others.

The fact that many people know about this is due in large part to the efforts of a non-profit organisation called the International Service for the Acquisition of Agri-biotech Applications (ISAAA). For the last dozen years, each February, the ISAAA has succeeded in attracting considerable attention from traditional and social media for the publication of its reports on the 'Global Status of Commercialized Biotech/GM Crops'. This series of reports, published annually since 1997, has applauded one milestone after another, breathlessly documenting the spread of transgenic crops across more acres, onto more farms, and into more countries. The raw data in these reports (collated from obscure sources and always presented in the most flattering possible light) are invariably wrapped in enthusiastic commentaries which attribute this progress to the manifold benefits of transgenic technology: its productivity, convenience, effectiveness and profitability.[1] This success narrative has become a widely repeated story of GM crops in global agriculture – a story of radical and progressive technological change that has been embraced by literally millions of farmers, the great majority of them smallholder producers in the 'developing world' (Glover 2010a).

More than a few commentators have suggested that these farmers' openness to transgenic crop technologies puts the 'selfish' and 'irrational' anxieties of affluent European consumers into a shameful perspective. Unlike the well-fed Europeans, goes this argument, impoverished cultivators and hungry consumers in the global

South cannot afford to turn up their noses at this vital, safe and productive technology. The narrative implies that European opposition is the chief obstacle to an even more rapid and enthusiastic adoption of transgenic crops by farmers and consumers in poor countries (Paarlberg 2002; Taverne 2007; Collier 2008).

The research presented in this volume puts this narrative to the test, using an innovative combination of social science research methods to investigate the ways GM crop technologies have been received in three of the world's 'rising powers': Brazil, Mexico and India. The researchers spent time observing, interviewing and discussing GM crop issues with national scientists, groups of smallholder farmers and urban consumers in each of the three countries, culminating in deliberative workshops that brought these diverse groups and other stakeholders together.

The researchers found that the spread of GM crop cultivation did not necessarily mean that farmers and consumers were all completely comfortable or satisfied with the technology. In fact, transgenic crop technologies have proved quite controversial and unpopular with some stakeholders in all three of the focus countries. Both growers and consumers said that they felt ill-informed about the technology, its environmental and socio-economic implications, and its prevalence in agriculture and the food system. They felt excluded from decision-making and suspected the motives of agribusiness companies, entrepreneurs, large-scale farmers, politicians, and regulators.

Scientific experts were more likely to dismiss public concerns and argued that the development and deployment of transgenic technologies was rightfully an urgent priority for the sake of national prestige, scientific competitiveness, economic development and food security. Yet in some cases, younger scientists were more likely to have reservations about the necessity and benefits of genetic modification. They worried about ecological effects and sustainability, and did not necessarily share the confidence of previous generations in the inevitability of achieving social and economic progress through modern technology.

These observations will undermine the complacent assumption that the 'rising powers' have definitively resolved the controversy over transgenic crops, and that the future will inevitably see these countries race ahead in GM crop technology. On the contrary, countries that have long been said to be on the brink of embracing transgenic crops in a big way, notably China, have in fact wavered for many years without committing themselves wholeheartedly (e.g. see Normile 2014; for commentary on the complex politics of GM crops in China, see Chapter 7, this volume). Supporters of transgenic technologies typically blame environmental activists and campaigners for causing this delay by stirring up public anxiety (e.g. see Cao 2014), but the research reported in this volume confirms what other scholars have observed in Europe, the UK and other jurisdictions: activists' campaigns against GM technology would probably have had less traction among consumers and publics if citizens had greater confidence in the way the technology is being developed and governed (Alam 2011; Grove-White *et al*. 1997; Gupta 2011; Levidow 1998; Levidow and Carr 2010; Wynne 2001).

One interesting aspect of the project is the exploration of remarkable differences between Brazil, Mexico and China. For instance, it is quite widely known that maize (corn) occupies a central place in the cultural traditions and identity of Mexicans, but soya in Brazil is an introduced crop without traditional culinary associations, which is produced largely for animal feed or for export. Cotton in India is an intermediate case: a non-food crop whose history is, nevertheless, intimately linked with that country's experience of colonial exploitation. Differences like these help to explain why national controversies over genetic modification have followed different paths.

Nonetheless, there are common themes across the three cases. In each of the countries, one can see evidence of struggles between different agricultural interests and contrasting visions of agricultural development and modernisation. All three countries in varying degrees have bifurcated agriculture sectors, where distinct systems of large- and small-scale farming exist almost in parallel. By and large, transgenic crops have fitted comfortably into a productivist, industrial, commercial vision of large-scale agriculture, supported by agribusiness, financial investors and wealthy landowners. In more or less explicit opposition to this manifesto, an alternative vision has been pushed by agro-ecologists, environmental campaigners and champions of smallholder peasant farming, who reject transgenic monocultures in favour of low-external input, biodiverse and organic farming methods, wrapped up in narratives of food sovereignty and sustainable rural livelihoods. (Other possibilities – such as the proposition that transgenic crops might be open-source and accessible technologies compatible with small-scale and low-input farming techniques, and not exclusively grown in large-scale industrial monocultures – have achieved little traction.)

Generally speaking, governments have stood alongside large-scale farmers and agribusiness interests in support of transgenic technologies, yet (in countries such as India) smallholder producers are so numerous and (in countries such as India and Mexico) agriculture is often so evocative of national identity and culture that their voice has been impossible to extinguish. In all three of the focal countries, smallholder producers have exerted considerable influence on public and policy debates about biotechnology in agriculture and food, in rural life and urban consumption.

In my view, one of the project's most troubling observations was of a pervasive breakdown in public trust in institutions of science, governance and regulation. It is especially troubling to learn how little confidence and trust smallholder farmers have in the scientists and technical advisors of the agricultural extension services, agro-dealers and seed companies, who should be helping them to solve their farming problems. When agricultural technicians and farmers freely blame one another for problems that are beginning to appear in transgenic cropping systems (such as pest resistance and herbicide tolerant weeds), and neither accepts responsibility for their part, we have evidence of a serious breakdown in a key relationship that should be helping humanity to achieve global food security and sustainability in the decades ahead. This rift is alarming, because international experts and policy-makers are counting on this broken relationship – implicitly or explicitly –

to help drive new techniques and technologies into farming practice, so that global agriculture can address pressing problems such as growing enough food, adapting to climate change and mitigating the adverse environmental effects of intensive farming.

The research reported in this volume helps to clarify why claims that the debate about transgenic technologies is 'over' are very wide of the mark.[2] Patently, the debate continues because disagreements continue to exist, even in countries like India and Brazil that are widely believed to have taken up GM crop technology with great enthusiasm and success. We should expect that the debate will continue so long as there remain contentious issues and disagreements of substance between societal stakeholders. Pretending that public concerns about transgenic technologies have been stirred up by political manipulators, or trying to insist that they are founded on ignorance or bad faith, is no way to proceed. That the disagreements have not yet been resolved is partly due to the intractability of the issues at stake – the conflicting interests and competing visions are intrinsically difficult to reconcile – and partly because of clumsy and disingenuous attempts to close down the debate and impose regulatory closure. In other words, as this report demonstrates rather well, these ongoing disagreements reflect failures of democratic governance.

As well as shedding helpful new light onto this governance breakdown in Brazil, India and Mexico, this research also helps to internationalise narrow British and European public debates about transgenic crops and foods, and about the relationship between agricultural technoscience and socio-economic development. In particular, the researchers involved in this project challenge citizens, governments and experts to fill the 'institutional void' that exists where a more legitimate, inclusive and effective governance system for GM crops should be. They propose the adoption of a framework for responsible research and innovation resting on four pillars:

- better *anticipation* of future developments in science and technology;
- wider *inclusion* of diverse stakeholders;
- more *reflexivity* among scientists and technology developers; and
- better *responsiveness* to societal needs and problems.

What would these four pillars deliver? The project authors invoke a handful of important concepts to flesh out their proposal, including *stewardship* and *deliberation*. I highlight these again here because I believe that they are important keywords that underpin the concept of responsible innovation, and thereby responsible technological governance.

The idea of stewardship is essential to responsible innovation because it means taking responsibility for the consequences of one's activities. Stewardship means taking care. It means accepting one's duty to be mindful of and accountable for the effects and impacts of the techniques and artefacts one produces and disseminates. It is the opposite of frivolousness or flippancy and therefore it eschews lazy claims that with such-and-such a technology all will necessarily be well. It rejects the cliché, normally accompanied by a metaphorical shrug, about technology being intrinsically neither good nor evil, as if we cannot help what bad people may do with our innovations and therefore we need not even try. Acknowledging that technology may be used for good or evil ends, the good steward takes steps to anticipate those potential ends, to consider their implications, to promote beneficial effects and reduce adverse impacts by amending designs or by cooperating with others in legitimate frameworks of governance. Recognising that one's actions might have negative as well as positive consequences for others means engaging with a wide range of stakeholders to think about those impacts, and reflecting on one's own purposes, interests and behaviour. And it necessarily implies being willing and ready to respond to the legitimate claims of others and being answerable to them in the fulfilment of one's ethical duties.

In other words, the responsible innovation AIRR framework (as set out in chapter 1, this volume) is a coherent expression of stewardship, or key components of it, and it implies that the ethical innovator is not a shirker of responsibility, not careless or thoughtless, nor reckless with the lives of others or the welfare of society at large. Deliberation is essential to this model because considering the wider societal implications of a technology is not something that can or should be done privately, as it were in a conclave open only to technical experts. This follows for both ethical and practical reasons. Public deliberation is necessary because the stakeholders potentially affected by new technology require an opportunity to be informed and to have their concerns taken into account. Deliberation is needed because the potential impacts of technology are uncertain and need to be drawn out thoughtfully and mulled over. Practically speaking, both the legitimacy and the effectiveness of policy decisions hinge on the ability to demonstrate that the implications have been carefully considered and discussed by relevant stakeholders.

Author biography

Dominic Glover has been engaged in research on agricultural biotechnology topics almost continuously since 2000. His work in this area has focused on biotechnology politics, policy, governance and regulation at the global level and in countries of the global South (Glover and Keeley 2004; Glover *et al*. 2004; Stone and Glover 2011).[3] He has investigated the role played by transnational agribusiness corporations in the development and commercialisation of transgenic crop technologies, and their efforts to shape and influence public and policy discourse about the relevance of biotechnology for global food security, poverty reduction and agricultural sustainability (Glover 2002, 2007a, 2007b, 2007c, 2010a; Glover and Newell 2004). He is one of a small number of academic researchers who have closely studied the peer-reviewed literature on the performance and socio-economic impacts of transgenic, insect resistant cotton among smallholder cultivators, particularly in China, India and South Africa (Glover 2010b, 2010c).

Based on his research in this area, Glover has provided expert advice to international organisations including the office of the United Nations Special Rapporteur on the Right to Food.

Notes

1 See www.isaaa.org/resources/publications/briefs/default.asp (accessed 27 August 2014).

2 Among others, the prominent pro-GM campaigner Mark Lynas (2013) has sought to close down discussion about transgenic technologies by insisting that they are safe and that nothing else remains to be discussed: 'So my conclusion here today is very clear: the GM debate is over. It is finished.'

3 See also 'Outputs' at www.ids.ac.uk/project/agricultural-biotechnology-and-policy-processes-in-developing-countries (accessed 27 August 2014).

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9

AN ANTHROPOLOGICAL PERSPECTIVE ON THE PROMISE AND THE THREAT OF GM CROPS

Commentary by Penny Harvey

I have been fascinated to read the ethnographic accounts in the GMFuturos research, of the specific controversies that GM crop technologies have provoked in Mexico, Brazil and India, not least because they are so resonant with the debates that surround the introduction of new technologies more generally. Technological innovations court controversy because a technical procedure never stands alone from, nor external to social processes. I have a long-term investment in the study of technological change. As a social anthropologist I have observed and analysed the ways in which the politics of cultural and colonial encounter are played out in Latin America (Harvey 2008; Harvey and Knox 2010, 2015). From the vantage point of long-term ethnography in Peru I have studied the introduction of new infrastructural systems – including communications (particularly roads), water, refuse and sanitation, and the technologies of literacy (standardised languages, modern schooling and bureaucratic regimes). Drawing on this work I have also done fieldwork in the UK on digital technologies, IT systems and most recently on how big data might, or might not transform the management of waste disposal in Greater Manchester (Harvey 2009). The topics perhaps seem bizarrely diverse but they all converge on the modern promise that surrounds the potential of technological change to create new, improved futures. Notions of progress infuse all these technological stories. So too does the whiff of failure. Scholarly literatures on both possibilities abound, depending on which perspectives are championed by the researcher – see, for example, Scott (1999), Mitchell (2002) or Latour (1993) for diverse accounts of how technologies do and do not make a difference. Furthermore, the controversies that technologies generate are not only between developers and end-users, but also among and between intellectuals, politicians, development workers and grassroots social movements.

Contemporary ethnographies of technological change have recently been working with the concept of the ‘assemblage’ to think through how it is that technical systems mobilise controversy (Anand 2011). The assemblage refers to the various material and social relations that inhere in any specific technological device and/or system. Despite the appeal of their standardised form and accessibility, GM technologies are complex. They combine diverse knowledges, instruments and facilities. They invoke particular values, symbolic resonances, aspirations and expectations. Like all technologies they are also unstable in the sense that the processes through which GM crops are engineered, produced, and circulated constantly fluctuate in relation to changing and disjunctive economic and social interests, cultural dispositions and knowledge practices. The assemblage is a concept that invites historical analysis to explain how things come to be (assembled) as they are in any specific time and place, and how and why they change. And just as technological systems assemble or draw together diverse materials, techniques, affects, institutions, skills and knowledges, they also assemble 'publics' in specific ways as people come together around specific causes or issues that temporarily convene around a sense of shared concern (Hird *et al.* 2014).

The fine-grained ethnographic work on GM crop technologies offers us new perspectives on the specific contours of how GM technologies 'hold together' as a specific field of practice, and how they mobilise specific social groups in support or in opposition to their presence. However, such perspectives also suggest that the question 'Can GM feed the world?' is perhaps not such a good question, or at least a question that lacks precision. It shifts attention away from GM crop technologies as complex relational and dynamic technological processes by assuming that we already know which aspects of GM are in question. We might do better to ask what it takes to keep 'GM' stable enough as a concern for both proponents and opponents to argue their case. How do people convince themselves and others that they are talking about the same thing as they rally to support or oppose a technological system? This question is important as the ethnographic record shows how the GM crop debates absorb and replay other more general preoccupations to the point where it is not always clear what exactly is in question.

On the one hand it seems clear from the report that GM crop debates articulate competing ideas about the best ways to produce food. But this finding provokes a further question: 'best' for what? It is suggested for example, that people often prefer not to eat the food that they make money from. Thus, food that is good for making money, is not necessarily the same as food that is good to eat, or food that is good to exchange and offer to others. It is also clear that we should not assume the equivalence of GM maize, GM soya and GM cotton. These crops are not GM in the same way. From the perspective of some of the technological procedures there are clearly similarities, and there will be scientists who can learn much about the potential for genetic modification by comparing the results of their experiments with maize, soya and cotton. But if we suggest a general comparison of the effects of GM techniques on the production, circulation and consumption of specific crops then we find quite different understandings and experiences of gain and loss. GM maize as a staple food-crop with strong associations to a sense of national identify provokes different modes of engagement and rejection than the modification of cotton in India or soya in Brazil.

It is also not only the focus of debate but the ways in which the controversies over GM crops gather momentum that differ from case to case. It is important to note that GM debates circulate with an energy that derives from concerns well beyond the specifics of who the GM crops might feed and how. For example, the ethnographic accounts suggest that fundamental concerns about how to eke out a living from the land, gathers affective force as the possibilities and the dangers of living with GM fold in to the expression of concern about families and communities, about farming practices and feeding practices. In Paraguay where poor farmers argue that soya kills (Hetherington 2013) we find that their fiercest opponents are not necessarily the large corporations who have the resources to plant and maintain the required barriers to prevent cross-fertilisation. On the contrary the fiercest and most violent confrontations occur between those with few resources, some of whom have opted for the marginal gains of GM crop production, while others are wary of the new uncertainties and risks that GM technologies subject them to. The chances for life and death are unevenly distributed and most keenly felt by the poor. The arrival of GM crop technologies is as likely to amplify fears and tensions as to mitigate them. The key point at issue here is that GM crops imply radical changes in key areas of people's life worlds. The adoption of GM offers no guarantee of greater food security and for many people uncertainties increase.

Furthermore, in times when policies of deregulation are used to encourage business investment and when social responsibility is increasingly devolved away from state agencies to decentralised publics, there is often great uncertainty as to where the responsibility for protecting the 'public good' actually lies. In such circumstances entities like a GM crop can easily emerge as the focus of more diffuse fears, even as the epicentre of struggles for social justice and redress draw on long histories of exclusion and violently imposed inequality. In the light of these histories of inequality we need to adopt a radical approach to difference that does not settle for 'the cultural' as explanation but looks at how specific differences emerge, and grow in strength in this contested field. So we might usefully ask: how do the GM controversies themselves create 'publics' in a recursive process that thinks about how GM crops and the publics who accept, refuse or ignore them are mutually constitutive (i.e. wrapped up and entangled with each other)? The emergence and unfolding of GM crops in people's lived worlds produces the contours of controversy that both replay old histories and stimulate future imaginaries.

From the ethnographies presented it seems clear that GM crops cause problems in people's lived worlds because they are not simply about 'food', or rather 'food' isn't just about calories. Food is also about family, community, land, farming, cooking, feeding, taste, and so on. The introduction of GM crops requires people to experiment with these core relational dynamics but without any guarantee that the new ways of living will offer an improvement or even a viable way forward. The risks involved are not simply about 'health' in the narrow sense, but about a more general sense of uncertain futures. For this reason it is important to distinguish between practice and culturalist approaches in considering why people respond to technological innovation in specific ways. A culturalist approach seeks to explain differences in terms of beliefs, habits, local knowledges and understandings. In this framing, indigenous people, or peasant farmers are often assumed to be conservative and resistant to change, out of ignorance, fear and/or superstition. A practice approach by contrast looks more closely at people's practical activities and acknowledges a greater sense of pragmatic accommodation to the diverse possibilities that people encounter. Thus, rather than ask what any particular person thinks about GM (which invites them to conjure up an abstract category and an ideological response) it is often more appropriate to ask what difficulties do these crops produce for them, and what possibilities? Do they gain more secure food sources via GM crops? Are there other benefits? Do the needs and requirements of GM crops produce new and important relations for some, but not others? Do GM crops offer sufficient security to play out against sovereignty? GM crops clearly provide exciting projects for scientists, good investments for entrepreneurs and considerable hope for some small farmers. Asking these pragmatic, practice based questions will produce a whole range of answers. These diverse responses work against the stereotypes that so often confine the poor to categories not of their own making. Indeed in many parts of the world people find that their basic civic, even human rights are reliant on their capacity to convincingly inhabit the category of 'indigenous' by displaying unbroken cultural connections to ancestral values and practices that often have to be reinvented and reinvigorated as dominant regimes continually reconfigure who can be of value and how. The other advantage of the practice approach is that it promises to move beyond mutual accusations of ignorance or deceit.

I end with the sense that emerges from the ethnographies that some of those engaged in the GM debates think that 'interests' threaten the possibility of meaningful communication, to the extent that it might be better to search out disinterested voices to help resolve the tensions that GM crop technologies generate. I would suggest that it makes more sense to try to draw out people's interests and to make them explicit where possible, because interest is what energises the controversy. A controversy assembles publics who care. As researchers we work to find out what different people are interested in, what futures they are trying to create, what life worlds they are struggling to build, maintain or leave behind. If, as some of those represented in the study suggested, only those with no 'interest' can legitimately participate in these debates then we would indeed be opening ourselves to a frightening future. I would suggest that if only those who don't care are seen as reliable then uncaring solutions are likely to emerge.

Author biography

As Professor of Social Anthropology at the University of Manchester, Penny Harvey's research and teaching have focused on knowledge practices, with a particular interest in technological and infrastructural change in Latin America. Her most recent book, *Roads: an anthropology of infrastructure and expertise* (co-authored with Hannah Knox and published by Cornell University Press, 2015), is an ethnography of road construction in Peru, describing the encounters between engineering knowledges and other more local ways of knowing. The book describes the construction process, and explores the relational dynamics through which particular knowledge practices and knowledge forms become credible and actionable.

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10

NEOLIBERAL ORIGINS OF ANTI-GM PROTEST IN EUROPE

Commentary by Les Levidow

Symbolic targeting of GM products

How can one explain the enduring and widespread conflict over GM products? What can be learned from this experience for other new technologies? At the GMFuturos policy workshop in June 2014 several speakers echoed a complaint echoing those commonly voiced by proponents of GM technology since Europe-wide controversy arose in the late 1990s, namely that GM technology had been turned into a symbol of wider issues, such as corporate monopoly over the seed supply or the industrialisation of agricultural systems. According to some workshop participants, this symbolic targeting was unfair: why should GM crop technology be singled out for such blame? Such wider issues are set out in the GMFuturos working paper and are further elaborated in this volume. In particular, opposition movements had targeted GM crop technology as a symbol of neoliberal globalisation and/or of foreign-owned multinational companies in each of the three countries studied – India, Brazil and Mexico (see Chapters 2–5, this volume).

In all three countries, protest movements were led largely by peasant movements with broader reasons to mobilise against those neoliberal political-economic agendas, which were seen as extending farmers' dependence on input-suppliers. In India *Bt* cotton had become a symbol of struggle against multinationals, neoliberal logics, the US and globalisation (Chapter 4, this volume). In Mexico GM maize had become a symbol of a neoliberal political-economic model, especially trade liberalisation with North America (Chapter 2, this volume). In Brazil GM soya was initially opposed as a threat from multinational companies to small farmers' rights and native seeds, though soya as a foodstuff had a weak public resonance in that country (Chapter 3, this volume).

In each case, such symbolic targeting of GM crops gained a broad public resonance by linking various issues and constituencies. How and why did this happen in so many places? Why did opponents target GM technology as a symbol of wider issues? And was this targeting unfair?

Actors who make such complaints should examine the roles of their own institutions. These will be analysed here by drawing on my previous research. In Europe GM technology had been promoted as an instrument of a wider neoliberal agenda, aimed at linking government, public-sector research institutes and the private sector. In the mid-1990s some European politicians and policy-makers even warned, 'Any obstacle to GM would jeopardise globalisation and its benefits.' My short article describes the origins of this European political agenda, which became the target of a broadly-based opposition movement.

Agricultural biotechnology linking EU neoliberal agendas

In the early 1990s European policy frameworks adopted the US model of intensive industrial modes of agricultural production as an inevitable pathway. As a broad category, agricultural biotechnology (henceforth agri-biotech) came to symbolise European progress through the adoption of a clean, precise technology that promised to link environmental and economic sustainability, especially through reductions in agrochemical usage. A biotechnological vision was promoted as an overall solution to the problem of European competitiveness: through biotechnology, the argument went, European companies would be able to compete in an increasingly competitive global market, involving the adaptation and consolidation of European companies into competitive multinational corporations. As part of this economic objective, an essential ingredient would be the application of modern biotechnology to European agro-food industries. The European Commission thus promoted biotechnology as central to Europe's future (Gottweis 1998: 170).

Within a neoliberal policy framework, moreover, a 1993 White Paper counselled European adaptation to inexorable competitive pressures, stating: 'The pressure of the market-place is spreading and growing, obliging businesses to exploit every opportunity available to increase productivity and efficiency' (CEC 1993: 92–93). The imperative to adapt was linked to the imperative for radical technological innovations including biotechnology: 'The European Union must harness these new technologies at the core of the knowledge-based economy' (*ibid.*: 7). The entire agro-food industry became discursively 'based on biotechnology', i.e. strategically dependent upon science-led innovation, including GM technologies, as essential tools for future growth and competitiveness (*ibid.*: 100–103).

Research and development for proprietary knowledge

This political agenda informed EU research priorities. According to the Fourth Framework Programme: 'In particular, efforts will be made to identify the science and technology options with the most favourable impact on growth, competitiveness and job creation in Europe' (CEC 1994). This agenda equated 'favourable' with being 'globally competitive'. Priority was given to innovations in the new genetics, seen as foundational to improvements in efficiency and competitiveness. State-funded research was designated to be 'pre-competitive': to develop basic knowledge that would facilitate downstream competitive innovations. Policies aimed at the 'life sciences' included strategies for industrial integration – between seeds and agrochemical companies, as well as between agricultural supply and pharmaceutical companies – as means towards R&D synergies as well as competitiveness. Such policies also foresaw the European agri-supply industry becoming integrated into multinational companies.

By the early 1990s European Community funds for biotechnology research were made dependent upon industry partners committing resources to any project proposal. Research was given a clear economic function, with 'more careful attention to the long-term needs of industry'. According to managers of the DG-Research Biotechnology Division, 'The most vital resource for the competitiveness of the biotechnology industry is the capacity to uncover the mechanisms of biological processes and figure out the blueprint of living matter' (Magnien and de Nettancourt 1993: 51, 53).

This research agenda conceptualised nature as an information machine whose deficiencies had to be corrected, so that such improvement would strengthen European industrial regeneration and competitive advantage. Molecular knowledge was promoted as key to industrial competitiveness. Within the domain of agriculture, research sought to delineate precise genetic changes that could safely protect crops and enhance agricultural productivity. This R&D agenda complemented the wider aim to 'industrialise agriculture', in the words of a lobby group for GM crops (GIBiP 1990).

As newly prioritised in agricultural research, the pursuit of molecular-genetic knowledge facilitated the extension of proprietary knowledge. In 1988 the European Commission proposed a directive granting property rights in 'biotechnological inventions', whose title incorporated a basic concept from the agri-biotech industry, representing discovery as invention. Opponents raised the slogans 'No patents on life!' and 'Criminalise biopiracy!'. They warned against several harmful consequences: that the directive would provide an incentive for companies to use GM techniques rather than other methods of improving seeds; that plant patents would deter other forms of seed improvement, especially of non-GM seeds; and that the mere prospect of litigation could deter other plant breeders from using the germplasm of GM crops.

In the ensuing controversy, 'biopiracy' became a common term for the theft of genetic resources – but with two opposite meanings. For advocates of greater patent rights, 'biopiracy' meant violating the rights of an inventor, by using patented materials without a licence agreement or without paying royalties. For opponents of such rights, 'biopiracy' denoted the patents themselves, on the grounds that biological material should remain freely reproducible as a common resource.

Under state pressure to become more 'demand sensitive', public-sector research establishments (PSREs) moved towards a more business-oriented organisational culture. This blurring of the public–private boundary became an imperative for PSREs, not just an opportunity. As some governments reduced core funding for research, public-sector scientists underwent pressure to seek greater funds from private sources. Moreover, some public funding was shifted from PSREs to universities, which more rapidly expanded into new areas and which more readily utilised short-term funding (e.g. by employing contract researchers). Core funding was reduced or transferred to output financing (i.e. dependent upon competitive bidding for specific projects). In the agro-food sector, these pressures stimulated a shift in priorities from agronomic methods to molecular-level research seeking patentable knowledge. These shifts undermined the public-service roles of PSREs and their public credibility as independent experts, especially when risk controversy arose (Levidow *et al*. 2002).

'Risk-based regulation'

The controversy over GM crops and foods was intensified by neoliberal regulatory frameworks. For many years, some experts and regulatory officials had anticipated that GM crops could generate herbicide-tolerant weeds or pesticide-tolerant pests, thus complicating crop-protection methods. But official EU risk assessments classified such effects as merely normal 'agronomic problems' rather than as harms that should be considered as necessary components of the risk-assessment methodology. This normative judgement accepted the hazards of intensive monoculture, while also conceptually homogenising the agricultural environment as a production site for standard commodity crops (Levidow and Carr 1996). This regulatory framework complemented a wider project to reconstruct Europe as a 'smooth space' for freely exchanging goods within the internal market, which remodelled society and environment according to a free-market model (Barry 2001).

Thus early EU regulatory procedures incorporated the neoliberal assumptions of agricultural biotechnology promoters. Under 'risk-based regulation', societal decisions were reduced to a case-by-case approval of GM products within a narrow definition of technical risk. Moreover, scientific ignorance was institutionalised and portrayed as scientific knowledge, especially through the refusal or failure to design risk research appropriately, as well as through character assassination of scientists who attempted to do so (Levidow 2002). This 'risk' framework complemented the wider aim to industrialise European agriculture. Regulatory procedures authorised 'safe' GM products, which could then enter the EU internal market as extra options for farmers. They would have the free choice to buy more efficient inputs for global competitiveness. As unwitting consumers of GM food, the public was imagined to be willing supporters of what was considered a beneficial technology. Within this neoliberal model of rational market behaviour, European publics had little scope to act as citizens.

Multi-issue target

By promoting agri-biotech as an instrument of a neoliberal agenda, the EU system provoked great suspicion and opposition, which grew from the mid-1990s onwards. GM crop technology was turned into a symbol of anxiety about multiple threats: about the food chain, agro-industrial methods, unforeseen and long-term hazards, state irresponsibility and political unaccountability through globalisation. From 1998 onwards, the controversy often gained large public audiences through the mass media, as well as active involvement of many civil society groups. They took up slogans from small activist groups as well as from high-profile campaigns of large NGOs.

Together these activities developed citizens' capacities to challenge official claims and in the process created new civil society networks demanding state accountability. European citizens were told that they must accept agri-biotech, yet this imperative was transformed by civil society actors into a test of democratic accountability; public debate became a forum for deliberating societal choices (Levidow and Carr 2010). Various protest organisations and associated publics attacked the European Commission's neoliberal framing of the GM crop agenda as a ready-made, multi-issue target. Critics emphasised the above linkages within the agendas of those institutions (including the Commission) that were promoting agri-biotech. Yet proponents of the technology complained about unfair or irrational targeting; they distinguished between a benign technology and its external context or consequences.

Lesson-drawing?

In explaining the public controversy on GM crops and foods globally, the GMFuturos project diagnoses an 'institutional void' (i.e. a deficient institutional capacity to address important political and cultural issues beyond those of technical risk; see Chapters 1 and 5, this volume). At least in the European Union, however, the fundamental problem has been arguably the converse, namely that such issues were pre-empted by institutional commitments. These were devised to further industrialise European agriculture, to extend proprietary rights to seed varieties and to define 'risk' narrowly as the definitive basis of regulation. The overall neoliberal framework provided a common target for diverse societal groups across Europe. This broad mobilisation was analogous to the pattern that has arisen in many countries of the global South, especially those studied in the GMFuturos project (India, Brazil and Mexico).

Many writers have drawn lessons from the controversy in Europe, both for the adoption of GM products there and for the governance of other novel technologies. Some commentators have drawn dubious lessons. For example, according to one commentator: 'The easiest way for the nanotechnology community to avoid the problems experienced in the deployment of biotechnology is to provide accurate information and encourage critical, informed analyses' (McHugen 2008: 51). This appeals to a deficit model, attributing the earlier public controversy to a deficiency of publicly available information. In practice, greater public knowledge highlighted linkages between GM products and neoliberal policy agendas, thus generally increasing public opposition (for a more detailed critique of the deficit model of science communication, see the section on 'Science and publics' in Chapter 1, this volume).

Another commonplace lesson is that the next novel technology could become 'another GM' if the public is not adequately consulted at an early stage, and that greater public involvement or deliberation could help to avoid societal conflict over technological innovations. For example, according to Gaskell, 'Given the opportunity to deliberate on such innovations, the public voice can be expected to be measured and moderate' (Gaskell 2008: 257). Notwithstanding the benefits of improved public dialogue, both of those lessons decontextualise public responses to the technology from its political-economic settings and agendas.

As a different lesson for the future, any technoscientific issue unavoidably has a political-economic dimension which can take various forms and trajectories. Power struggles arise over how to define the issues at stake, even the nature of the technology. By institutionally foreclosing these issues at an early stage, as was done for GM crops and foods in Europe, proponents provoked public controversy. Leaving the trajectory open for public deliberation has yet to be tried as a democratic experiment.

Acknowledgements and sources

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Author biography

Before and during the rise of protest against genetically modified (GM) crops and foods throughout Europe, Les Levidow had the opportunity to research the conflicts and consequent regulatory changes. He studied interactions between EU institutions, member states and civil society protest. To analyse these dynamics, his research drew on interdisciplinary approaches linking perspectives from sociology, political science, and especially science and technology studies (STS). Through his involvement in more than six research projects during a fifteen-year period (1989–2005), Levidow attended numerous public events, organised several multi-stakeholder workshops and carried out over a hundred interviews with key actors.

This work included three research projects funded by the European Commission on the regulation of GM products; another Commission project on the shaping of GM innovation trajectories; and two research projects funded by the ESRC examining the UK's regulatory approach to GM crops and foods, within efforts towards EU regulatory harmonisation and within trans-Atlantic regulatory conflicts. This research provided the basis for two books (Murphy and Levidow 2006; Levidow and Carr 2010), four special issues of journals (Carr 2002; Levidow and Carr 1996, 2000, 2005) and over thirty journal papers (see acknowledgements section above).

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11

GM FUTURES

Perspectives from a plant molecular biologist

Commentary by Keith Lindsey

The genetic modification of plants for human use has been with us much longer than that of precision genetic engineering. Ever since the dawn of farming about 10,000 years ago, genetic diversity was the basis for the selection (probably unconscious at first) of strains with improved yield and associated characteristics (such as for example reduced scattering of seeds by the plant, which facilitated collection by the early farmers; Tanno and Wilcox 2006). The basis of this and other traits is embedded in the DNA of the crop, but it was not until the work notably of Charles Darwin that it was recognised that species are not immutable, and indeed they change form and function (their 'phenotype') over time, in response to selection pressure; and it was Gregor Mendel who demonstrated that the phenotype of plants was heritable in a predictable and mathematically quantifiable manner. Neither Darwin nor Mendel were aware of each other's work, and it was some years before it was realised that the two sets of observations were linked mechanistically, such that the hands of natural selection (and indeed artificial selection, as carried out by the early farmers) and evolution use as their clay the genes, embedded within the DNA of inherited chromosomes (the 'genotype'), moulding them to generate new forms. Pioneering breakthroughs in understanding the mechanisms of genetics over the last 100 years or so has led to new and more targeted approaches to plant breeding, with genetic engineering being a recent and controversial addition to the toolbox available to breeders.

Many biologists have a particular view of the nature of life, not shared with all. I personally hold the view that life is a fundamental property of the Universe, in the same way as both matter and energy are. I have every expectation that life will be found throughout the cosmos, where environmental conditions (the availability of water, organic molecules, light, suitable temperatures) prevail within ranges that allow molecules to self-organise and replicate. This is what we can imagine happened on planet Earth almost four billion years ago. The first chemical fingerprint of life on this planet is found buried in ancient sedimentary beds in Western Australia, which date back 3.8 billion years; the first microfossils are 3.5 billion years old, and look rather like modern photosynthetic bacteria (Mojzsis *et al.* 1996). Today we find similar organisms deep in the Antarctic ice, and in hot springs. Life can survive and evolve in the most inhospitable environments.

So I do not see life as something mystical (though it is truly marvellous), but rather I want to understand how it works, what biophysical and chemical and genetic processes take place, and how they are integrated, to produce a living organism. And I do not feel concerned about manipulating these processes (i.e. about 'interfering with nature'), if that knowledge can prove useful, and subject to the regulatory processes that govern the ethics and safety of biological research.

Modern genetic engineering techniques have developed from fundamental research into the molecular biology of organisms – the structure and function of DNA, RNA and proteins that define the genotype and phenotype of all life on Earth, from virus particles to plants and animals, including humans. Intriguingly, many genes have been found to be conserved between organisms as diverse as yeasts, plants, sea urchins and humans – genes controlling how cells divide, for example (Lew *et al.* 1991) – and this kind of work shows how similar genes are between widely different forms of life. The genes controlling limb development in flies are very similar to those controlling limb development in humans (Manak and Scott 1994); the same is true for genes involved in the development of the gut across the vertebrates (Bates *et al.* 2005). This kind of understanding leads biologists to view life in a particular way – that genes are very similar between many kinds, if not all, of life on Earth, reflecting their common origins billions of years ago.

And this information leads many biologists to take the view that exchanging genes between organisms is not in itself so bizarre a phenomenon, as in fact many genes have transferred between organisms through the course of evolution (Richards *et al.* 2006; Boto 2010), and change within evolutionary lineages has been selected for. Furthermore, new capabilities in rapid genome sequencing techniques (spelling out the genetic code for entire organisms) has revealed that the genetic variation between individuals of the same species (whether plant or human) is much greater than previously imagined, and certainly more extensive than the relatively small changes of one or at most a handful of genes modified through plant genetic engineering (Long *et al.* 2013; Maher 2012).

For me, this suggests our focus for new crop breeding should be not on whether a gene has been transferred by recombinant DNA technology ('gene cloning', as is currently the case in Europe and several other countries), but on developing a broader problem-based system for ensuring the world is adequately fed, that there is security in energy and water supplies, that there are adequate medicines for dealing with major problems of infectious diseases and an ageing world population. Many of these problems may require GM-based solutions, amongst others (which will include non-scientific solutions, i.e. political and societal ones). But to exclude GM because it is GM is not, I my view, a justifiable approach.

Many will disagree. Many feel that GM is no solution, because it is controlled by multinational companies, or is unsafe, or is being forced onto society without wider consultation. Some clear views emerged from the GMFuturos project. In Mexico, it was felt by some that GM reduces genetic diversity. In fact it might well be argued that introducing genes from wild relatives of crops increases, rather than decreases, genetic diversity. The first GM potatoes in the UK were engineered using virus resistance genes from the wild potato relative *Solanum brevidens*, which, because it is a different species, cannot be crossed in to cultivated potato (Gibson *et al*. 1988). This exemplifies how the available gene pool (genetic diversity) can be increased for breeders. More recently, resistance to the potentially devastating potato late blight pathogen *Phytophthora infestans* (the cause of the nineteenth-century Irish Potato Famine, but which is still a threat) has been introduced into potato also from sexually incompatible wild relatives, with advantages evident in terms of reduced use of chemical sprays and increased yields (Jones *et al*. 2014). In regard to the perceptions of biodiversity problems in Mexican maize, it might be useful to think about issues surrounding preservation of historic germplasm, rather than a perceived loss of diversity from the introduction of GM technology for specific purposes.

In Brazil, scientists were enthusiastic about GM approaches but felt they were losing control of their crop breeding, and so the benefits of their work, to multinational companies. A real problem here is the cost of regulation for new GM crop varieties. It is estimated to cost companies several millions of dollars to produce the data required for regulatory assessment, and only multinationals, with very large financial resources, are able to fund this work. As a consequence, small independent research teams in SMEs or public institutes are unable to meet the costs of taking novel germplasm through to market. A regulatory system is essential for safety testing and to provide the kinds of safeguards society demands of new products, but the current system is arguably disproportionate, expensive and certainly restricts commercialisation of badly needed new crops to the very large companies.

In India, many interviewed were also in favour of the potential value of GM crop technology, but scientists felt their voices had not been listened to by politicians. More broadly, the public in many countries feels that decision-making over the application of GM has been taken out of their hands, a general lack of consultation. So what can be done?

There are some lessons for GM and new breeding techniques to be learned from the UK's Synthetic Biology Roadmap, and the associated public engagement activities.[1] Here, the approach has been not to *inform* the public about the benefits of the new technology, but to *engage* in discussion, to invite comment, to develop some kind of common view. This can assist decision-making about whether to spend public funds on solving global problems to which GM technology may contribute (note that currently relatively little UK public funding is used for developing GM crops). It is my perception that many fellow scientists have significantly shifted in their ways to present their ideas to the public – less a case of educating (which is patronising), more a case of explaining their viewpoint and seeking comment. The way in which scientists at Rothamsted Research sought open discussion with the wider public in 2013 over the trialling of GM wheat modified for pest resistance (which did use public funds in its development) is an excellent example of this approach to engagement.[2] Such an approach need not be dismissive of evidence-based assessment of risks to human health and the environment (this must still surely be a cornerstone of a regulatory system), but the system should be able to take some account of other viewpoints, including potential benefits (which are not allowed to be considered under current EU regulations). Indeed, the current regulatory system in Europe does not solely depend on scientific assessment of risk – there are many examples in which diverse independent regulatory authorities have agreed that the adverse risks of a cultivating a given crop are negligible, but politicians have decided not to cultivate, on the basis of other, political, grounds. One possibility might be the establishment of a Social Advisory Group in parallel to the existing Scientific Advisory Group structures, from which Government Ministers could take advice; or, perhaps preferably, the use of Stakeholder Forums, that could consider the broader issues associated with novel traits or crop/trait combinations, which could feed in to the policy-making process.

The current European regulatory system is not 'fit for purpose'. It regulates on the basis of the method of generating a new crop variety – whether it used recombinant DNA technology or not. If it did, it is regulated; if not, it is not. This leads to inconsistencies. A herbicide-tolerant maize plant, for example, generated by GM technologies, including the latest precision 'genome editing' techniques, could be absolutely identical in both its DNA sequence and phenotype to a herbicide tolerant maize plant generated by spontaneous mutation. The two crops would therefore have identical impacts on the environment, yet the former would have to go through the expensive and time-consuming regulatory system, while the latter would not. The UK's Advisory Committee on Releases to the Environment (ACRE), which advises UK government ministers of risk associated with GMOs, has discussed limitations to the current European regulatory system and concludes that a product-based system, similar to the Canadian system, is more future-proof, given the plethora of new technologies emerging that do not fit well with the current definition of a GMO (summarised in Pollock and Hails 2014).

There is clearly a need for a change in the way science, politics and society meet to discuss new breeding technologies, if we are to address the pressing issues of feeding and providing energy for the world in a sustainable manner. GM can be part of the solution, but it should be considered alongside other technologies, wider engagement is to be encouraged, and the regulatory system should be freed up to avoid monopolisation by a few wealthy companies. Reform of current ways of working is bound to be controversial, but we face significant challenges if we are to meet the basic needs of a population of 9 billion by 2050, against a background of climate change, increasing urbanisation, competition for already limited resources and a growing need to protect non-market ecosystem services. It is therefore timely to consider future options for a more cohesive and relevant regulatory system, as the status quo becomes unacceptable.

Author biography

Keith Lindsey is Professor of Plant Molecular Biology and Head of School at Durham University's School of Biological & Biomedical Sciences. His research interests are in understanding molecular mechanisms of plant development. A graduate of Oxford and Edinburgh Universities, he carried out post-doctoral research at Edinburgh's Department of Botany and at the Department of Biochemistry at Rothamsted Experimental Station. He was appointed to a faculty post at the University of Leicester in 1989, before moving to a Chair in Durham in 1996. He is Chair of the New Phytologist Trust, which is a charity that promotes plant sciences, and until recently was President and Chair of Council of the Society for Experimental Biology, a member of BBSRC Council (BBSRC's governing body), and of the UK Government Advisory Committee on Releases to the Environment (ACRE, which advises government Ministers on GM-related issues). He is a Fellow of the Society of Biology and of the Linnean Society of London.

Notes

1 See www.rcuk.ac.uk/publications/reports/syntheticbiologyroadmap (accessed 15 December 2014).
2 See www.rothamsted.ac.uk/our-science/rothamsted-gm-wheat-trial (accessed 15 December 2014).

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12

THE SEARCH FOR AFFIRMING NARRATIVES FOR THE FUTURE GOVERNANCE OF TECHNOLOGY

Reflections from a science–theology perspective on GMFuturos

Commentary by Tom McLeish

The fascinating comparative research of the GMFuturos project, and the remarkable day's discussion at the Royal Society of London that followed it, underlined both widely differentiated global contexts for these contested technologies and commonalities in the experience of engaging different communities. For whether we were learning about the vexed symbolic role of maize in Mexico, the rescinding of *Bt* brinjal authorisations in India, or the calling for reopening of debate on GMOs in Brazil, the voices we heard were plural, often disconnected and dissatisfied with the quality of extant public process and conversation. The project also illustrated the inadequacy of any public discussion of technology which attempts to restrict the terms of debate to the evaluation and minimisation of technological risk and the maximisation of reward. As related projects have found in the context of nanotechnology, fracking and other environmentally modifying technologies (Macnaghten 2010; Macnaghten and Szerszynski 2013), other concerns will always come into play. If these narratives are not allowed to appear explicitly within the process of consultation, then they will do so by proxy, driving the debate, but not answerable to it from their hidden position.

In research on lay ethical concerns with nanotechnologies, the European DEEPEN project identified five narratives that appeared to be central in the formation of public concerns, namely, 'be careful for what you wish for' (the narrative of desire), 'Pandora's box' (the narrative of evil) and 'messing with nature' (the narrative of the sacred),[1] joined by 'kept in the dark' (the narrative of alienation) and 'the rich get richer and the poor get poorer' (the narrative of exploitation) (see Davies and Macnaghten 2010; Davies *et al*. 2009; Macnaghten *et al*. 2010). The philosopher Jean-Pierre Dupuy (2010) has developed a meta-analysis of the five narratives identifying the former three as 'ancient', in so far as they focus on the relationship between humans and 'nature' (or metaphysical entities) and the latter two as 'modern' in so far as they are concerned with political questions of power, access and distribution. Nevertheless, whether ancient or modern all five narratives are cast uniformly in a 'tragic tone', with little positive reflection on the underlying motivations of science. Furthermore, they tend to be implicit, rather than explicit, in any technological debate. So proponents of technology attempting progress at a level of simple risk analysis will simply be talking past any voices propelled by these deeply swimming stories of warning. We seem to possess no alternative narrative which might engage and work with them. The only narrative to hand, with a positive technological direction, is that of the 'modernist instrumentalist' narrative which presumes that science will inevitably lead to enlightenment and social progress, which fails to mount any effective challenge because it simply refutes them.

In the context of environmentalism more broadly, Bruno Latour has also pointed out that there is a lack of credible alternative to two extreme responses to the challenge of anthropogenic environmental decline: an impossible withdrawal from 'technology' to 'nature' on the one hand, and implausible further technological 'fix' on the other (Latour 2008). His conjecture is that: 'The real question is to have the same type of patience and energy as God the Creator Himself' and his appeal to the serious work of engaging technology using theological resources – what he describes as the need to 'love' the technology we have created – comes as surprising, even shocking, to a contemporary readership. Yet his point is to urge a marshalling of resources that will drive an understanding of the true interdependence that 'mastery' (of nature or of anything else) requires. To interfere and then withdraw, or to create and then abandon, is a technological transgression of potentially disastrous consequences. But Latour is not simply advocating another partner to the narratives of evil, the sacred, or desire. Nor is he working at an abstract or theoretical level – theology, certainly the best theology, can be intensely practical.

The 'missing narrative' implicit in the work of the DEEPEN project, Dupuy and Latour, if there is one, needs urgently to be discovered and explored. Here I draw on an interdisciplinary approach to a third narrative resource – that of the ancient wisdom literature.[2] After hearing that Pandora is alive and well in discussions around nanotechnologies, and that theology is needed to lead technology back to its environmental responsibility, perhaps this does not seem impossibly strange. I have developed the substance and consequences of a scientist's reading of the timeless and remarkable Book of Job elsewhere (McLeish 2014), but it is worth revisiting here for its strong resonance with both the present and absent narratives of the relationship between the human and nature, and as an alternative source of ancient narratives on which to reflect on the findings of the GMFuturos study. It might also be offered as one of the resources that Latour's project of a 'theology of technology' could feed on. The book of Job in the old testament is a text deeply and continually concerned with the natural world, and within its device of legal debate between contested voices (those of Job, his 'comforters' and ultimately that of God himself) creates an area in which different accounts can engage. The text offers six differentiated views of human response to the natural world that emerge from its complex discourse. It is striking, both how closely they map onto the narrative categories of the DEEPEN project in general, and how they serve more specifically as categorising tools when listening to the plural voices of GMFuturos:

- *Enshrining retributive moral law*. The well-known accusation of Job's comforters is that the suffering he has undergone must have resulted from his own wickedness (or from that of others closely related to him). In this brittle (and ultimately condemned) view, nature provides unequivocal returns on investment – good for good and harm for harm. But this closely parallels the narrative of exploitation. It surfaces today as well: in the GMFuturos research with Mexican actors, fears surfaced of genetically altered food being 'not good', that it will 'case harm and problems' and that such consequences are due to human greed.
- *Eternal mystery*. Invoked in the text as a device to silence Job's demands for justice as inappropriately arising from a darkened mind, this is an ancient form of the 'kept in the dark' narrative that frames nature as forever hidden and human ignorance as a permanent state. It is of course profoundly antithetical to natural philosophy and science, yet it still surfaces today. Even in the scientific communities we interviewed, there was expressed a doubt as to whether we understand enough of the genome (e.g. of maize) to be confident about modifying it.
- *Book of nature*. This form of the narrative of the sacred endows nature with coded messages for humans to read. In Job, natural phenomena are appealed to metaphorically in support of moral standpoints. We learn from nature but we do not attempt to modify our teacher. So an articulate voice, from a consumer's association in Mexico, advocated learning from the barriers to gene transfer that nature has enshrined.
- *Uncontrolled chaos*. The view of nature as capricious and out of control is that of the unjustly suffering Job himself. Essentially the root lies in the text of the link between the moral and cosmic worlds; Job's accusation is that God allows wild and damaging excesses in nature (the storm, the flooded wadi, the earthquake) as he does of the moral sphere (innocent suffering). One professional group we interviewed in India spoke of the inability to control nature, 'Something, anything, can happen …', even appealing to ancient (Mahabharata) mythology in support of their warning.
- *Object of worship*. Unfamiliar to the modern world, this response to nature is also only hinted at in the text, where Job denies 'kissing his hand to the moon'. But intransigent modern denials that such a reaction is ever an issue today look less convincing when arguments appeal, even implicitly, to the narrative of 'sacred nature'. 'We reject the approval of *Bt* brinjal. We traditionally save our own seeds and consider them as sacred', affirmed an Indian farmer in our study.
- *Way to wisdom*. There is another response to the natural world that the ancient text on Job describes in a way that differs radically from all the foregoing in

> its radical openness, and in its elevated view of both human responsibility and human potential. I have elsewhere called this narrative the 'way to wisdom' (McLeish 2014). It draws on a coherent dualism of knowledge paired with insight into nature, whose historical arcs connect with contemporary science and technology. However it brings these strands of understanding Nature's structures and wisdom in using them, in much closer and more complex relationship than the linear and unidirectional framing currently exemplified in national science policies and strategies. It also affirms that it is deeply significant of human nature to interrogate and to husband the world. Bringing into life as yet unrealised potential within nature is not necessarily an inappropriate 'playing God', providing that it is not driven by an anthropocentric avarice. The essential rebalancing, in this radical narrative, of a purely exploitative manipulation of the world is provided by the twin imperatives of an ethics of human responsibility and a theology that centralises and prioritises the wellbeing of the world before the wealth of human beings. It provides a worked answer, rooted in very long tradition, to Latour's call for a 'servant mastery' in relation to the environment. Some of the more thoughtful reflections of scientists as identified in the GMFuturos research represent a path that balances openness to the new with recognition that care is needed to avoid unanticipated consequences – so in Brazil, for example, we heard, 'it is necessary to use technologies in an integrated and combined manner. The exclusive use of a specific technology can lead to imbalances', yet 'Genetic Modification is seen as allowing for the indefinite extension of human intervention in nature.'

The challenge is to create a functional contemporary connection between an approach that draws on the 'way to wisdom' and the process of policy creation around troubled technologies such as GM crops. The potential to break the current forms of deadlock evinced in all the examples of GMFuturos, no less than in the UK and EU, is provided by its doubly radical content. An example of the challenging thinking that science helpfully unlocks is Keith Lindsay's point (Chapter 11, this volume) about the occurrence of near-universal genes. On the one hand it makes a positive affirmation that human intervention in nature can be both a good, and supportive rather than destructive of the human condition. On the other it challenges and ultimately condemns any framing that makes its principle goal the material benefit of people, in this case, the 'feeding of the world' narrative. This must be secondary to a deliberate prioritisation of a sustainable world. So Michael Northcott reminds us (Chapter 13, this volume) of the socially evolved sustainability of the small farmer in the context of *poïesis*. Introducing a set of principles built on such values within a fraught contest between 'technological progressive' and 'ecological conservative' voices sides with neither. It contains fundamental directions that both will embrace, yet presents both with severe challenges as well. But, like all third views, it also diverts the deadlocked opposition characteristic of all discussion that has been reduced to a simple dualism.

Such are the potential benefits of reframing the value-structure of debate around an explicit, rather than implicit, set of underlying narratives. But any implementation begs severe questions of process and definition. How should the prioritisation of 'responsible care' for nature be articulated, weighted and defined? How can a language of negotiable underlying narrative be developed and deployed? How can the different levels of discussion and consultation recognise multiple levels of motive that play out, whether we make them explicit or not, and in particular, how can a positive narrative such as the 'way to wisdom' be led to engage with, for example, 'Pandora's box' in a way that unlocks a real deliberation about new technology rather than an entertaining sideshow? If nothing else, we need to create a deliberative framework that recognises the sterility of any idea that all that needs to be discussed is at the level of risk.

Author biography

Tom McLeish's scientific research over the last 25 years has contributed to the formation of the new field of 'soft matter physics'. Interdisciplinary work with chemists, chemical engineers and biologists has sought to connect molecular structure and behaviour with emergent material or biological properties. He has also worked intensively with industrial researchers developing molecular design tools for new polymeric (plastic) materials, leading large national and international programmes, with personal contributions mostly theoretical. Throughout he has also maintained an interest in public engagement with science, science policy and public values including the underlying, but often hidden, public narratives of science. He has been especially interested in the potential for theological narratives to inform debates in science and technology, both explicitly and implicitly. He explores historical, sociological and theological approaches to contribute to a long cultural narrative for science in the recent book *Faith and wisdom in science* (McLeish 2014), whose framework he adopts here in a reflection on lessons from the GMFuturos project.

Notes

1 See Chapter 14 of this volume for more on this narrative in the GM context.
2 A Hebrew development of ancient wisdom parallel to that of the Hellenistic *poïesis* discussed by Northcott in Chapter 13 of this volume.

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CROP SCIENCE, THE HEISENBERG PRINCIPLE AND RESISTANCE TO GENETICALLY MODIFIED ORGANISMS

Commentary by Michael S. Northcott

Research on diet and nutrition at a conference organised by the Scottish NGO Nourish in June 2014 revealed a swathe of problems in Scotland associated with modern industrial farming and industrial food procurement procedures. These include the prospect of the population being 80 per cent obese or medically overweight by 2030 from eating an inappropriate diet, growing ground water and atmospheric pollution, reduced animal welfare in planned larger animal factories, dramatic declines in native species on farmland, and a broader cultural disconnect between food consumers and farmers (Nourish 2014). The conference outcomes revealed a preference among the delegates – who included smallholder farmers, small food business people, academics and public health experts – for kinds of foods and farming that are less dependent on agrochemicals and large machinery, and for greater availability to people of wholesome foods in the form of whole grains, vegetables, pulses and reduced protein of animal origin.

In the closing panel of the conference Iain Gordon, a crop scientist from the James Hutton Institute, made the claims that GM crops are essential for feeding the world, including Scotland; that they are a form of 'natural selection'; that the scientific case for them is based on 'evidence'; and that the alternative case as set out in the conference outcomes – for reducing use of agrochemicals, improving animal welfare, reducing reliance on large industrial and mechanised farming, and recovering a more localised food supply which produces more fresh food for human consumption and less for animal feeds – was merely 'advocacy' with no basis in 'science'. The conference had reviewed unambiguous scientific evidence on the negative outcomes, in terms of the environment and human health of the present food system. But for the crop scientist, to resist technological innovations in crop science and food manufacture was 'anti-scientific'.

Mutual incomprehension between crop scientists and an informed lay food-eating public is a frequent feature of the public debate around genetically modified

(GM) crops and foods. I first encountered this mutual incomprehension as a member of a research project on the ethics of GMOs by a team of researchers who included crop scientists, social scientists, philosophers and theologians. The outcomes of our deliberations took the form of a collaboratively written book which was published just as the controversy over GM crops and foods spilled over into a major public campaign against them (Bruce and Bruce 1999). The very fraught and public debate led to the widespread banning of GMOs in human foods in Europe. GMOs were viewed by European regulators as novel organisms because the mix of genes the new methods made possible – such as the insertion of a fish-derived anti-freeze gene into a strawberry plant – could not occur under natural selection, or in conventional plant breeding techniques. But in North America GM foods were widely introduced into the human food chain without significant public debate. This was because the United States Food and Drug Administration adopted the claim of some of those involved in patenting GMOs that food crops derived from these patents were 'substantially equivalent' to non-GM foods and therefore required no special licensing, labelling or regulation (Herrick 2005).

The claim that GM crops were substantially equivalent to conventional crop hybrids rested upon laboratory investigation by crop scientists, who might be said to have an interest in the outcome of the chemical composition of GMOs (Novak and Halsberger 2000). But no investigations of the effects of these new substances on mammals beyond 30 days were undertaken before the claim was made, although long-term mammalian tests are mandated by the US FDA for novel substances created in pharmaceutical laboratories using what can be claimed to be analogous biochemical technologies to those used in the creation of GMOs. Subsequent efforts by public scientists to investigate the long-term effects of GMOs on mammals were resisted by public and private agencies, and there remains a paucity of such studies (Pusztai and Bardocz 2006). Two published peer-reviewed studies of the effects of GMOs on the mammalian gut beyond 30 days of dietary introduction found significant toxic effects, including the production of cancerous cells in rats fed Roundup Ready maize for 90 days (Séralini *et al*. 2007, 2012). However Séralini's results were contested and, amid claims that his laboratory's methods were 'unscientific', the journal editors retracted the 2012 article.

Despite the suppression of scientific efforts to investigate the effects of a GM diet on mammals, there is growing controversy in the United States and other countries where GM foods have been introduced, concerning their effects on human health. Growing anecdotal evidence from farmers and consumers, some of it published in the grey literature, indicates increasing concern about the effects of GMOs in foods (Smith 2005). There is also scientific evidence of environmental and reproductive health problems in humans associated with glyphosate, which is the most widely used herbicide on GM crops engineered for herbicide tolerance (Richard and Moslemi 2005). Hence a number of state legislators in the United States have begun the process of attempting to pass state laws requiring the labelling of GMOs in foods in their states. The first state assembly to pass such a law was that of Vermont, and this state assembly is, at the time of writing, being sued by a coalition of American food processors (Hallenbeck 2014). The contested background of GMOs in the developed world has been of concern to food corporations, governments and venture capital investors who see biotechnology as representing significant economic benefit to private corporations and to public science laboratories.

Against the background of growing controversy over GM crops and foods in the developed world, the GMFuturos project was funded by the John Templeton Foundation to investigate whether the widespread adoption of GM crops in developing nations provided any lessons for understanding (and potentially overcoming) the controversy in North America and Europe. However, the project research outcomes reveal precisely the same disconnect between crop scientists and the lay food-eating public that characterises the GM crop controversy in Europe and in North America. They also indicate that the disconnect between agricultural science and sustainable farming is not unique to GM crops but a broader feature of the science–food relationship. One of the first and best known discussions of this disconnect is a collection of essays by the Kansas farmer and essayist Wendell Berry. In *The unsettling of America* Berry (1977) described the demise of the family farm in North America, and argued that it was the result of efforts to increase crop outputs using novel technologies as promoted by the Federal Government funded Land Grant Universities. The mechanised, chemically dependent, and monocrop agriculture these universities researched and commended was responsible for the destruction of the old settler culture of small farms in the American Midwest and South (*ibid*.). For Berry, food and farming are about human culture and ecological community, and when they are treated as being purely about maximising economic production of a small number of favoured crops, the richness and resilience of human communities as well as ecological diversity and resilience are diminished.

The GMFuturos research data reveals how percipient is Berry's analysis for the unfolding saga of GM foods in Mexico. Mexico is the origin of the largest social movement in human history – La Via Campesina (Redclift 1980). This movement originated in the 1980s among peasant farmers and urban food growers and consumers who saw that the mechanisation, chemicalisation, and hybridisation of corn, and other staple foods, threatened both the ability of Mexicans to feed themselves in the future, and put at risk the enduring cultural pattern of food growing on small plots which for many Mexicans (those not living in big cities) remains central to a good life (Montoya 2010; see also Chapter 2, this volume). Montoya's research on the symbolism of food in Mexico reveals that cultural meanings around maize growing and meal preparation are ontological, sociolinguistic, moral, politico-economic and spiritual (Montoya 2010). They are situated in embodied relationships between peasant farmers, cooks and householders, and hence between people and land. When an agricultural system that neglects these is imposed on a people it inevitably courts political controversy, including contestation over GM foods. The laboratory interviews, as well as the interviews with farmers, in the GMFuturos project reveal that this relationality between people and land, culture and agriculture, is missed by crop scientists whose primary training has tended to be focused on maximising production of an individual crop in a laboratory or on a university or crop institute plot (Thompson 1995). In other words when agricultural science is primarily about what is done in a food laboratory, absent of considerations of what impacts what is done in the laboratory will have on farmers, food consumers or other species, then the likely outcome will be a growing disconnect between science-informed farming and the health of farming communities, of farming ecosystems and of food consumers. Hence science is not neutral for those interviewed for our project in Brazil (Chapter 3, this volume). Instead they perceive GM crops, and the advocacy of them by multinational corporations, as a value laden and politically and economically portentous project which locks farmers into dependence on expensive hybrid seeds, and an expensive and polluting chemical arms race against increasingly herbicide resistant weeds.

The reflexive nature of the nature–culture relationship in agriculture is at odds with the perception of science–society relationships held by many in the scientific community, and among the corporate funders of much scientific research. That laboratory science and physical reality are reflexive was first proposed by Walter Heisenberg who argued that laboratory instruments such as electron microscopes are capable of modifying the behaviour of the physical subjects their users investigate, and this finding is now called the 'uncertainty principle' or the Heisenberg principle (Heisenberg 1958). The Heisenberg principle was brought into popular culture by the influential US TV series *Breaking Bad*. The main protagonist of the series, Walter White, is a chemistry teacher in Albuquerque, New Mexico who develops lung cancer, treatment for which his health insurance does not fully cover. To meet the costs of treatment, and to provide financial security for his family on his death, he sets up a mobile methamphetamine laboratory with a junky who has contacts with drug sellers. He makes exceptionally pure crystal meth and the product acquires a mythic reputation, and White then acquires the market name 'Heisenberg'. And as the name becomes established so the bodies start piling up. White/Heisenberg fails to insulate himself or his laboratory from the death-dealing drugs market, and becomes caught up in successive acts of violence among those he chooses as partners in crime.

Breaking Bad works well as a metaphor for GM crops. GM crops are more 'pure' from a scientific perspective than a Mexican farmers' inherited seeds. They are designed for a specific purpose and with laboratory instruments: each gene has been charted, counted and inserted at a level of microbiological precision that is unavailable outside of a highly insulated and 'clean' laboratory. But this 'clean' lab underwrites the belief that a laboratory made crop will not influence the environment, the farmers, the eaters and other species who interact with it. And hence GMOs manifest even more deeply than non-GM crop science the mechanistic and reductionist frame of scientific epistemology. But this frame is subject to reflexive uncertainty: as Heisenberg observed, the scientist who studies atoms using an electron microscope influences their behaviour and so her findings are influenced by her interrogative practices. Insulation does not work.

Breaking Bad is also a critique of economic neoliberalism where human health and human suffering are merely data that generate pricing signals, or transactional friction, in anonymised procurement chains of goods and services in deregulated and privatised market economies (Pierson 2013). For Vandana Shiva, the most influential Indian campaigner against GM crops in the third GMFuturos study area (Chapter 4, this volume), GMOs are products that are deeply intertwined with neoliberal economics (Shiva 2006). This is because GM crops offer private corporations such as Monsanto the ability to privatise gene races and hence the fundamentals of human food cultures on every continent, and Monsanto in particular have pursued that corporate goal with considerable success, and despite extensive resistance from civil society.

Poïesis is the word given by classical Greek philosophers to the unique capacity of humans to generate and sustain aesthetic and ethical ideals through their creative powers on earth. For Plato, makers such as craftsmen and cooks, when they combine knowledge of the ideals with their practices of making, become exponents of the 'liberal arts' just as do philosophers or sculptors (Plato 2005). True makers, who express the grammar of *poïesis*, enhance goodness, truth and beauty in the given order, and their craft practices are shaped by the political virtue of justice. In these conditions making becomes the source of freedom from mere drudgery, or slavery. This same conception of *poïesis* is found in other ancient stories, including those of Jews and Christians, about the cultural powers involved in making, including the making of food (Northcott 2005). In the origin story of the Jewish people their ability to grow food on their own plots of heritable land is seen as the source of their freedom from the slavery of collectivised agriculture in Egypt (Northcott 2015). Similarly, in Christian history, cultures of farming, and of crafts and workshops, become sources of freedom when they are mediated by communitarian craft Guilds, and land distribution patterns that enabled yeomen farmers to flourish and restrained the powers of nobles and princes.

The gradual neoliberal collectivisation of agriculture by private corporations repeats earlier collectivising projects from ancient Egypt to Maoist China, and it threatens the same losses of freedom and sovereignty that these earlier collectivisation projects imposed on the peoples subjected to them. The contemporary neoliberal collectivisation project in the spheres of food growing and making is underwritten by scientific agriculture, and GM crops in particular, because the expert knowledge which creates them, and the high cost inputs required to grow them, are in the vanguard of this new collectivisation project in the developing world which transfers power and deliberation over the growing and making of food from farmers and householders to private corporations (Northcott 2003). Resistance to GM crops in the developed, and developing, world reflects not only uncertainty about the risks of GM foods to the environment or to human health. It also resonates with the reflexive relationships between culture and agriculture, and between political freedom and distributed powers over land and making. Neither the walls of the science laboratory, nor the biota free environment of the petri dish, can isolate the products created therein from contestation over these relationships.

Author biography

Michael Northcott is Professor of Ethics in the School of Divinity in the University of Edinburgh, Scotland with research interests that include agrarianism, genetically modified foods, environmental ethics, the ethics of new technologies, and climate change. He is PI of the AHRC/ESRC-funded Caring for the Future through Ancestral Time: Engaging the Cultural and Spiritual Presence of the Past to Promote a Sustainable Future research project. He is also a gardener and food grower, author of *Place, ecology and the sacred: the moral geography of sustainable communities* (Bloomsbury, 2015) and *A political theology of climate change* (SPCK, 2014), and a contributing author in *Engineering genesis: the ethics of genetically modified foods* (Earthscan, 1999).

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14

INNOVATING GOVERNANCE?

Commentary by Judith Petts

Since the mid-1990s, my work has often been driven by the problems and dilemmas of specific government decision-makers, not least when they are faced with apparent public opposition to new technologies that experts believe are 'safe' but citizens do not. The work therefore has been oriented to providing understanding and guidance on how to enhance governance within local, regional and national contexts. So, my own research has brought me face-to-face not only with the public contexts in terms of perceptions and concerns about risks, but also with the policy-making priorities of different experts, and not least the dilemmas and difficulties of encouraging new approaches to policy-making and the governance of innovation under conditions of uncertainty.

For me, therefore, the findings of GMFuturos have delivered a strong sense of déjà vu, not least in terms of understanding the importance of context in driving public responses to GM crops together with identification of the need to develop new kinds of risk and governance conversations. This is certainly not to suggest that the findings are not useful. They are. I am struck particularly by the resonance with current international discussions of responsible innovation. I will return later to a fundamental question prompted by the research: why, given all the evidence on the need for new modes of risk governance and public engagement has this largely not happened? But first, I must reflect on the essential message of the research and that is the power of context and the threat to fundamental values in determining responses to risks.

The power of context and the threat to values

We have long known from multiple risk perceptions studies that it is the activities that create a potential risk that people can be concerned about and fundamentally the institutions that are responsible for managing these activities that are questioned, often from a position of distrust. Cross-cultural surveys of risk responses have all identified differences in risk judgements depending on the political, cultural and socio-economic basis of different countries (Renn and Rohrmann 2000). The evidence from multiple studies identifies four dimensions of response: (i) experience and networks, (ii) the preference for the status quo, (iii) the adverse response to risks that seem to threaten basic social and human values, and (iv) the importance of the allocation of responsibility for management.

We know that social interactions, context and setting (spatial/physical, experiential, social) all play a role in shaping the sense that people make of, and the way in which they construct, any specific risk issue (Horlick-Jones 2008; Petts 2014; Petts *et al.* 2001). Collective memory and the 'expertise' that comes from direct experience when combined with the impact of everyday social practices are powerful influences on responses to risks of all types (what is known as the availability heuristic; see Tversky and Kahneman 1973). Responses vary across cultural and socio-economic contexts simply because memory, experience and social priorities differ.

Given this, the primary findings of GMFuturos could readily have been predicted. But being founded in the richness of dialogue and narrative the research findings contribute powerful and valuable case studies of how individuals and their social networks respond when faced with an issue that is embedded in complex and novel science. In the case of GM crops, the power and impact of knowledge and experience derived from direct working and social experience of farming, of crop production, and of food and material use in everyday family life are confirmed as particularly important. Maize, cotton and (to a lesser extent) soya are powerfully symbolic, but also basic and historically valuable, crops in the three countries. The introduction of GM varieties has been largely externally driven rather than initiated or necessarily desired locally. Therefore, it is questioned, contested and reviled among many despite widespread adoption, particularly in Mexico and Brazil.

We know that across all cultures individuals value the status quo. The simple explanation is that keeping with what you know and are familiar with is generally the easier, less stressful option in life. Overriding the status quo requires commitment to change and also takes effort (Fleming *et al.* 2010). Often such change has been explored in studies of the siting of new technologies and over 30 years strong international understanding has developed across multiple contexts of the resultant 'not in my back yard' (NIMBY) responses to potentially hazardous facilities. Interestingly, GM Futuros confirms some similar characteristics in social responses to GM crops. While in this sense the wide-scale planting of GM can more readily be equated with a new activity as opposed to a new facility given its geographical spread, nevertheless detrimental impact on existing lifestyles as well as distrust in the robustness of the risk control institutions are common dimensions of the public risk response.

Further, like many responses to major industrial developments there are clearly highly contested sets of opinions and a lack of a shared understanding of the benefits of the new technology. Perceptions of power as much as perceptions of risk are evident. As the study concludes, GM crops in the three countries symbolise the wider struggles against unequal land ownership, rural survival, and self-sufficiency among the poor. As with many hazardous industries there is evident concern about the accelerating pace of science and technology innovation and most intriguingly evidence of the willingness of both 'sides' to mobilise science to support their claims.

In this regard, I am struck by the resonance with the NIMBY literature, where the public's willingness to contest the science and risk assessments has been seen as a surrogate for deeper concerns about threats to the status quo and to social values. The latter are not easy to argue in formal and expert-driven decision processes. This is even less so in political cultures where power imbalance is acute. Arguing instead about the robustness of the risk science can seem a more practical and effective intervention by public opponents than attempting to argue about the impact on personal livelihoods and ways of life (Petts 1997).

Multiple studies including this one, suggest that negative responses to GM crops are less about the potential risks to the environment and health and more about concerns about 'mucking around with nature' and inadequate controls. This perception is based in experience of regulatory and management controls (and failures of) across multiple, apparently unrelated, hazards. For example, the fact that GM crops have met with such vehement public reaction in the UK compared to the US has been linked at least in part to experience of the institutional management of the bovine spongiform encephalopathy (BSE) issue – risks that clearly are entirely unrelated but which both speak to issues around the intensification of agriculture and the transboundary movement of hazards.

EU–US regulatory differences in agricultural policy have been analysed in terms of the different cultural and economic meanings of agriculture (Levidow 2001). In the US, farms are regarded as more akin to factories often separate from nature and wilderness, whereas in Europe farmland has more traditionally been regarded as an integral component of the environment with farms a traceable guarantee of food quality. EU agricultural policy has been moving towards less intensive, high quality production and hence is more cautious of biotechnology. The US in contrast has seen a drive to enhance the market for high agricultural productivity and in GMFuturos the fear of the power of the transnational companies in driving governments' endorsement of GM is evident. For the governments of Mexico, Brazil and India three interlinked and powerful outcomes seem possible: agricultural improvement and enhanced public access to safe and nutritious food, massive national economic benefit, and raised national scientific and technological standing. The question is whether innovation for such benefits can be achieved responsibly?

Responsible innovation and engagement

The notion of responsible innovation has grown in importance recently and notably in European policy circles. Emerging technologies create the possibility of new opportunities not offered by nature. But opportunity is often accompanied by uncertainty and, indeed, sheer scientific ignorance. These uncertainties are not purely around the physical harms, but also in the kind of futures societies wish for and the purposes and motivations of innovation. As GMFuturos confirms, innovation is often acting in different cultural and economic settings which impact directly on notions of what is the 'right' and 'responsible' thing to do.

Governance of responsible innovation is being discussed in terms of a new adaptive framework which implies a move away from top-down, risk-based regulation to one that attempts to set the parameters of a system in which people and institutions behave such that innovation achieves desired outcomes (Roco 2008). This framework privileges anticipation, reflection, deliberation and response (Owen *et al.* 2013), placing an onus on innovators to reflect and listen to societal concerns and governance systems that develop social intelligence around the direction and control of technology (Lee and Petts 2013). This is also reflected in GMFuturos' proposed AIRR (anticipation–inclusion–reflexivity–responsiveness) framework.

Calls like this for public engagement in risk governance are far from new. Risk governance literature has consistently stressed the principles of communication and inclusion and the integration of all relevant knowledge and experience into decision-making – both at policy and project levels. The risks and benefits of new technologies have to be debated and reflected upon, precisely because they cannot be considered in terms of 'how safe is safe enough' but rather how much uncertainty is the collective willing to exchange for some benefits' (Van Asselt and Renn 2011). Since the 1990s, analytic deliberative approaches have increasingly been tested as potential means to counter failures to recognise different framings of risk (Renn *et al.* 1995). However, such testing has often been 'downstream' around the point of application of technologies, and has consistently identified that the real concerns and questions are usually about the need for the technology in the first place, about why people/organisations want to develop it, what they are going to gain from it, and what other impacts it might have (i.e. questions of purpose, motivation and unforeseen risks). The voices arguing to go 'upstream' in terms of deliberation and public engagement (see, for example, Pidgeon and Rogers-Hayden 2007; Macnaghten and Owen 2011) have become loud and persistent.

But certainly in the UK, governmental views of this have still often been restricted to promoting understanding and debating fears in a *potentially* controversial technology in advance of significant application (as has happened around the multiple UK public debates around GM crops; Pidgeon *et al.* 2005). New modes of governance that attempt engagement are often still about risk regulation than a more vital discussion about science, values and societal expectations (Stilgoe 2007). The UK's 'Sciencewise' programme attempts to build confidence and experience among policy makers in more upstream public engagement.[1] The programme celebrated its tenth anniversary in 2014, and there is little doubt that progress has been made in the recognition that the opening up of governance is essential and open policy-making now has political support. But while the 'deliberative-turn' (Goodin and Dryzek 2006) certainly seems to have captured policy attention, direct experience suggests that government narratives are still more about 'gaining public support' as opposed to notions of collective reflection and responsiveness. One problem is that when done well (i.e. when they are inclusive, informed, and open to challenge) deliberative public engagement is relatively expensive, is time-consuming and certainly is skills demanding. Questions are currently being raised by at least one UK government department as to whether public engagement is the same as social research and if so, to what extent the 'findings' count as evidence for policy-making alongside that from the natural, physical and engineering sciences.

In my view there is an urgent need to understand why the repeated calls for more public engagement in risk and technology governance are still only being responded to in a relatively lukewarm fashion, even in democracies like the UK that arguably are at least more sympathetic to the notion of its potential value? The reasons are undoubtedly complex but if the conclusions of projects like GMFuturos are to have tangible impact there is a need to tackle this question in a more systematic fashion and not least in the context of political cultures that are considerably less likely to be receptive and sympathetic even to the argument for change let alone to instigating good practice.

In the UK, the Royal Commission on Environmental Pollution (2008) introduced the concept of ongoing social intelligence gathering as a preferred approach to understanding how societal views and responses to the risks of new technologies are developing, viewing one-off public engagement as often time and context limited. My final reflection is that the evidence from GM Futuros confirms that even when technologies are in widespread use (as in the case of GM crops in Mexico and Brazil) this does not mean that they are necessarily accepted by, or acceptable to, all groups in society. Monitoring how public debate is developing over time in different social and political contexts is absolutely vital. In research terms this speaks to the power of longitudinal studies. In policy terms it speaks to the importance of anticipating how the knowledge and mood of civil society is developing and changing in order to proactively respond – whether with new information and education or enhanced regulation or more responsible innovation.

Author biography

Judith Petts is Pro-Vice-Chancellor (Research and Enterprise) at the University of Southampton, a member of Defra's Science Advisory Council, a member of BBSRC Council and chair of the BIS Sciencewise Steering Group. Her contribution to the GMFuturos end of project workshop was in relation to questions on the institutional innovations required to involve citizens in the governance of GM crops. Her qualifications for this task derive from over 20 years of applied research in the design, testing and evaluation of enhanced modes of risk communication and new forms of public engagement in decision-making (particularly around contentious and risky technologies). This work has always been context-specific in terms of both types of risk (e.g. incineration, nuclear waste, flooding, synthetic biology, geoengineering) as well as different cultural, economic and geographic contexts. While she has not personally undertaken research on GM technologies she has explored a number of issues that have similar characteristics in terms of high uncertainty as to the risk, and low public trust in the science, decision-makers and industry. Her own research and government advisory work, while primarily UK-based, has involved engagement and comparison with research and evidence in similar fields in the US, Australia and several European countries (i.e. different governance and socio-economic contexts, but similar risks). Within the international risk analysis field she has contributed to increasingly lively debate as to the means to enhance governance frameworks.

Note

1 See www.sciencewise-erc.org.uk (accessed 15 December 2014).

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15

INSTITUTIONAL RIGIDITIES AND IMPEDIMENTS

Agricultural research and GM crops in India

Commentary by Rajeswari S. Raina

The history of agriculture in the twentieth century is a history of technological and institutional change. Much has been written about technological change in agriculture: from high yielding varieties of crops (including pest resistant and herbicide tolerant GM crops) and animal breeding programmes, to chemical and irrigation technologies. Agriculture has also undergone significant institutional change both in developed and developing countries, from the provision of subsidies for chemical fertilisers, the development of intellectual property rights, norms for cooperative marketing, farmer producer company rules, participatory plant breeding protocols, model acts or laws for agricultural education, trade regulations, foreign direct investment directives and international agricultural research mandates. Yet, the significance and evolution of these institutional changes are less discussed and researched, especially when compared to the technological changes associated with and facilitated by these institutional innovations. This brief comment is about institutional change, defined here as new or modified rules, norms and habits of thought that govern and shape technologies, their uses and the participation of users in decision-making. I use the history of Indian agricultural research to examine these institutional dynamics and their evolution, making the case that what is seen as an institutional void in the GMFuturos project may actually be an organisational or structural void, maintained by prevalent institutions or norms and their rigidity. I will argue that the regulation of GM crop technology, and the capacities for responsive and inclusive decision-making, exist in a context where the institutions governing agriculture and agricultural research continue to resist learning.

Institutionalisation of models

Globally, agricultural production and development efforts 'have focused on improving seeds and ensuring that farmers are provided with a set of inputs that can increase yields, replicating the model of industrial agriculture', with a linear centrally controlled supply of external inputs (UN-HRC 2010: 5). There are several institutional arrangements that govern organisations in the industrial model of agriculture. Intellectual property rights (IPR) regimes protect the intellectual property embodied in seeds, chemicals and machines that belong to private and public sector research organisations. Governments support the adoption of these appropriable intellectual outputs or technologies with institutional arrangements that include financial incentives and subsidies. These institutions are a product of a common global legacy which began with the Hatch Act in 1887 in the USA, the formulation of the Development Commission and public funding of agricultural research in 1910 in the UK, and so on right up to several variations of the Bayh-Dole Act (since 1980) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement (since 1995). These institutional arrangements collectively enabled the industrial appropriation and substitution of agricultural inputs and outputs (Friedmann 1988), alongside the convergence of agricultural policy with science and technology and with global trade. The governance of any development in agriculture needs to be located within the norms of this model of industrial agriculture.

Norman Borlaug, the father of the Green Revolution, used his 'missionary zeal' to 'transform the Latin and Asian temperaments' in the agri-food sector (Raina 2009, quoting from Eric Stakman). Following the Green Revolution in the mid-1960s, Indian agricultural research and the administration of agriculture were reorganised to ensure 'far-reaching central authority and a clear line of command and execution' in order to 'meet the challenge of growing more food' (Agricultural Production Team 1959: 6), leading to the centralisation and consolidation of agricultural science under the Indian Council of Agricultural Research (ICAR). The administration of agriculture, mainly through extension services and agricultural education were likewise standardised through the development of administrative norms and a Model Act (1966) for all state agricultural universities. Plant breeding techniques, especially the defensive research strategies of the 1940s and 1950s, which combined horizontal resistance with desirable crop traits in local or provincial research programmes, were soon replaced. Crop-specific offensive research strategies were promoted to build higher yield responses (using chemical inputs, irrigation and dwarf plant varieties) and to develop vertical resistance to one or two specific pests and diseases.

Through the 1970s and 1980s, these norms were criticised for their reductionism, both in how they framed the problems of agriculture and in their proposition of technological solutions (Anderson *et al.* 1982). Accordingly, the politics of agricultural revolution involved increasingly capital intense practices, leading to a variety of negative impacts (on natural resources, on small and marginal farmers, and on biodiversity), and were criticised for increasing risks, and for showing scant appreciation of local knowledge systems. Farmer participation and farming systems research were presented as answers to these critiques in the 1980s. But the dominant approach of top-down problem definitions and solution prescriptions prevailed. Within India and globally (e.g. as promoted by the Consultative Group on International Agricultural Research, the World Bank and multinational corporations like DuPont), this linear model of technology generation and input supply was accepted as *the* prerequisite to meet increasing food demands arising due to population growth. India's Green Revolution ended somewhere in the early to mid-1980s (Bhalla and Singh 2010). But the organisations and professionals trained to carry forward this approach launched a second Green Revolution in 2007, sharing the same problem definitions, understandings of risk, valuations of natural resources and labour, and an imagination of what constitutes agricultural development. The institutionalisation of these norms governing the industrial model of agriculture, marks arguably the biggest success of the Green Revolution in India.

Institutional memory

As the GMFuturos research demonstrates, the regulation of GM crops across different jurisdictions share a common trajectory of leaked or illegal seeds entering farms before the formal approval for GM crop production had been issued. In India, when high yielding varieties of imported Mexican wheat seeds were distributed by the Ministry of Agriculture to the state governments for official release for *rabi* (winter crop) in 1966, the state governments of Bihar (who returned two railway wagons of seeds) and Gujarat refused to approve them for release and cultivation in their states. B. Sivaraman, the then Secretary of Agriculture at the union government, notes in his memoirs (Sivaraman 1991), how he used the Bharat Krishak Samaj and the Young Farmers Forum to distribute the seeds in Gujarat, Bihar and Madhya Pradesh. The protesting state governments were told that these were autonomous bodies of the farming community, and they had the freedom to distribute anything they liked (*ibid*.; Raina 2011). This quasi-official leaking of planting material using large and medium farmers and their associations consolidated the union government's role in funding and designing research, education, extension and the administration of the agriculture sector, independent of the decisions of state governments (who remain formally responsible for the sector according to the Constitution of the Republic of India). In India, GM crops have brought one additional actor into this nexus, the private seed and chemicals industry, contributing to the policies and programmes of the union government, agricultural science and technology (S&T) and large-medium farmers. A consequence of this centralised arrangement is that science policy and administrative actors feel little need for transparency or for broad participation of state governments, marginal and small farmers, and other rural and urban stakeholders.

Regarding India's cotton producers, we must note that the Indian peasant has rarely figured in the institutional memory of cotton in India: a crop whose experimental exigency was prompted by the colonial master's loss of assured supply of American cotton, whose scientific cultivation and selective breeding was designed to suit the looms in Manchester, and whose genetic features and physiology were altered (from native diploids to tetraploids and hexaploids) to produce desired staple lengths for India's own power looms. Peasant farmers have been the least consulted of all stakeholders in decisions about cotton production technology. In the 1970s, scientists and policy-makers had articulated the concern that the shift to tetraploid and hexaploid cottons would make the crop more susceptible to pests. By the 2000s, it was clear that cotton was being grown on 5 per cent of India's available arable land but was consuming 50 per cent of the nation's overall pesticide use. Public sector research generated hybrid long staple cottons, and later private multinational research inserted the *Bt* (Cry 1 Ac) gene into these varieties. Farmers were not consulted. There was little expressed concern that *Bt* cotton ought to have had farmer's participation in decision-making about the technology, its specific features or adaptive research or its commercialisation processes. Transparency and accountability to the farming community (or the ecosystem) have never been requirements in India's agricultural research and administrative decision-making processes.

Institutional rigidities

The GMFuturos project also found a lack of transparency in the regulation of GM crops and limited public faith in the very capacities of these regulatory bodies and their expertise; aspects that were found to be common across India, Brazil and Mexico. In India, public sector scientists who were supposed to provide independent evidence for policy-makers and politicians to make decisions were seen to be biased in favour of GM crops, and even in one case to have plagiarised reports produced by the private sector in their attempts to answer the technology choice concerns articulated by politicians (Menon and Sidhhartan 2010). As scientific evidence was set out, both about the benefits and the risks of GM crops, supported by industry and civil society organisations respectively, the union government's decision swayed between a moratorium on GM crops (including field trials) and granting approvals for field trials (TEC 2013; Menon 2014). The political deliberations on GM crops signified the inability of the established scientific and political leadership to address the persistent institutional rigidities of an agricultural administration and science and technology system that remains euphoric about the technological successes of the Green Revolution and thus incapable of systematically anticipating the impacts of GM crops on society, ecosystems and least of all on science. In India, GM crops remain a beacon for a scientific research system that has been accused of focusing exclusively on irrigated-chemical intensive agricultural production, of causing significant environmental degradation, of being incapable of addressing hunger and malnutrition, and of being marked by technological fatigue and weak and inadequate infrastructure and services (Planning Commission 2008; NDC 2007). In the face of institutional rigidities and inadequate political will that preclude reform of public and private sector research, GM crops offer a distraction from the institutional sclerosis and a possible panacea for paradigm maintenance.

The plant breeding and genetics led research and development paradigm is now on a diminishing returns phase (Ruttan 2005). But the institutional rigidities do not permit scientists and policy-makers to appreciate the success of alternatives like pest management coalitions that have effectively reduced pest incidence and pesticide use. The National Centre for Integrated Pest Management's successful programme for pest surveillance and management (NCIPM, 2009–12), and its new Crop Pest Surveillance and Advisory Project (CROPSAP, 2013–14) in Maharashtra, is one such example. Following the commercial release of *Bt* cotton, entomologists and pathologists have been labouring for a decade, addressing cotton pest outbreaks and protection measures (Vennila 2006). The question '*Bt* cotton for pest control or pest control for *Bt* cotton' raised by these scientists, points to two major institutional rigidities that resurface in the GM crop debate. These are (i) the norms of selective problem perception and (ii) silver bullet technological solutions (Rondinelli 1983). GM crops are ideal technologies to maintain the institutional rigidity of the dominant paradigm of agricultural production, led by crop breeding programmes designed to generate the maximum response of the living material to the chemical inputs and irrigation supplied. Of the 220 studies on socio-economic impact of *Bt* cotton in India (up to 2010), not one has compared the officially released *Bt* MECH hybrids with a non-*Bt* MECH hybrid (Ramasundaram and Vennila 2013). That the latter occupied 70 per cent of the area under cotton in Central India before the release of *Bt* varieties, is merely overlooked. There has never been a political demand for India's agricultural research system to learn about the dynamism and diversity of production contexts; the successful pest management coalitions like the ones headed by NCIPM or the many non-pesticide management programmes led by NGOs are either ignored or remain in isolated institutional niches.

Institutional learning

That leading scientists were compelled in 2013 to recommend an indefinite moratorium on open field trials of genetically-modified (GM) crops until the deficiencies in the regulatory and safety systems are effectively addressed (Supreme Court of India 2013), is evidence of the gravity of concerns about the institutional rigidity that persists in the agricultural S&T system. In the 1960s and 1970s, Indian agricultural research faced a spate of suicides by scientists (ICAR 1973). Concerns that agricultural scientists have about their profession and larger social goals continue to persist, even though such disquiet receives considerably less media attention than the well-publicised farmer suicides in the cotton growing central Indian states (Jishnu 2013). The persistent refusal of public sector research and the public administration of agriculture to learn lessons from these dynamics remains incomprehensible.

Today, many public sector agricultural scientists worry about the public-private partnerships that encourage them to sell their germplasm collections, professional time, labs and experimental plots to private industries, and associated dynamics of increasing centralisation, bureaucratic rigidity and reduced funding for research (Committee on Agriculture 2014; Jishnu 2013; NKC 2009; Raina 2014). Capacities to analyse changing contexts, to anticipate new actors and agendas, to identify expected and unintended consequences, are considered necessary by many. Agricultural scientists are aware that India's recent agricultural growth rates are driven by increasing commodity prices and not by productivity growth (Chand 2014), and that macro-economic policy is considering the withdrawal of subsidies that maintain a few technologies like chemical inputs (Planning Commission 2012), even though there has been a significant decline in incremental yield response to the unit application of these technologies (ICAR 1998; Vaidyanathan 2010; Planning Commission 2012).

Capacities for institutional learning and for the creation of new institutions or norms are needed in India and other developing countries, to promote agrarian alternatives, like eco-friendly pest management, organic agriculture and ecological agriculture (see UNCTAD 2013). The institutions or norms, regulations and performance criteria of these alternatives are commonly decided by or in consultation with local communities of farmers and consumers.[1] More importantly, these alternatives seem to build secure bridges between the 'isolated empires' of agricultural, environmental and health sciences (Ruttan 2005). The institutions or norms for farmer participation, agroecological system-based planning, collaborative behaviour for resource management are often recommended for reforming agricultural research. They engage with contexts, question the appropriation of knowledge, confront the messy politics of the current paradigm and bring in several new scientific research questions that advance both excellence and relevance of science (Scoones 2006; Feldman *et al.* 2010).

The GMFuturos research has revealed the failure of the 'public goods' norms that gave birth to public sector agricultural research and policy in India, Brazil and Mexico. The regulatory institutions or norms and appropriate structures or organisations needed for governing GM can be addressed only if we understand why there is continued political tolerance and support for technocratic decision-making processes. In order to address the institutional void in GM crop regulation and to enable more responsive and inclusive agricultural research, the persistent institutional rigidities, selective institutional memories and limited learning capacities that govern current agricultural research organisations and their contents must be addressed.

Author biography

Rajeswari Raina is a Principal Scientist at the National Institute of Science, Technology and Development Studies (NISTADS-CSIR), New Delhi. She has a background in the natural sciences and economics, and is a keen student of the interface between development policy and scientific knowledge, with a particular focus on the evolution and impacts of agricultural research. She is a researcher and advisor to various public, private and voluntary sector programmes on agriculture, the environment, natural resource management and economic development. Her work on GM crops and other emerging technologies uses institutional economics to explain the evolution of technological, social and ecological challenges in the agriculture sector.

Note

1 For example, see www.timbaktu.org (accessed 15 December 2014).

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16

FOCUSING ON GM CROPS

Commentary by Bob Simpson

As part of my contribution to the GMFuturos project workshop I was asked to provide a response about methodology in general and, specifically, the use of focus groups. My qualifications for taking on this task are a long-term ethnographic engagement with the reception of assisted reproductive technologies in developing world contexts. Specifically, I have been interested in the processes of vernacularisation, that is, the ways that novel technologies with global reach and capacity travel and become embedded in diverse social and cultural settings. I am also interested in the methodologies that might help throw light on these processes given that the issues in question are often sensitive and 'natural' methods are difficult to effect given that 'publics' are complex and diffuse entities to study and 'experts' are apt to be overly prescriptive and narrow in their engagement with social science research.

The request to provide a commentary on focus groups was perversely appropriate as, although as an anthropologist I have used them in the past, I am not a great fan of this method of fieldwork. My doubts about them arise from a sense that they are often taken unproblematically as a proxy for 'publics', they tend to cluster 'common' characteristics but inevitably elide others and they tend to stack up opinion in one direction rather than revealing the complex vectors that underlie the transposition of private views into public opinion. So, my initial response was 'Why couldn't they have asked me about ethnography, or something else that lands me in my methodological comfort zone?'

In engaging with focus groups in the GMFuturos study, however, it soon became apparent that there were some important things to extract from the focus group exercise. Indeed, focus groups as used in the research provided a crucial and effective strategy for dealing with the difficulty of accessing 'natural' settings and 'everyday' cogitation in relation to inchoate but, nonetheless, consequential controversy. What is interesting in my view about focus groups then is not so much individuals and their opinions but the way they are mutually and narratologically negotiated in this micro-forum (Kearnes *et al.* 2014). This take on focus groups draws attention to performance, language, relationships and significantly, for a contested issue such as GM, ways of dealing with difference and conflict in public arena. Looked at in this way focus groups provide us, not so much with a dipstick of public opinion, but a useful metaphor for what the GMFuturos research, in its call for new kinds of debate, deliberation and participation, has really begun to open up. With this rather different idea of what we might learn from focus groups we begin to move away from a simple traffic in information and opinion and towards the actual relationships and encounters between the dramatis personae in the GM debate: farmers, citizens, scientists, policy makers, representatives of agribusiness and so forth. Each operates with beliefs, imaginings, motives, fears, suspicions and, in turn, attributes these to others in the heteroglossic accomplishment of the focus group. This observation provides an interesting point of entry into the deliberative flow of people's thinking about GM technologies: where do these technologies come from, who brings them, why do we need them and what might they mean for us all?

A strong theme throughout the research in each of the countries in the project is that of attachment. People express their attachment to known and familiar worlds. This is articulated most cogently in relation to land, food, place, organisation and culture. In other words, these are the things that give them their sense of meaning, order and hope for the future or what Giddens, following psychiatrist R. D. Laing, referred to as ontological security (Giddens 1991). In contrast, these worlds are often troubled by various 'unknowns' that radically threaten these securities. For example, GM crops carry risks about safety and potential contamination which are difficult to 'know' and therefore difficult to assimilate into regulatory and policy responses to new technologies. Yet these are the things that animate public anxiety and suspicion (Grove-White 2001). These concerns and the responses to them, typically expressed in the register of risk assessment, are by now well-rehearsed. What the focus groups further reveal however, are other unknowns. These arise from a lack of knowledge and understanding about political processes, decision-making and the management of power and influence beyond the immediate worlds of household and the community.

Attempts to bring these kinds of unknowns under control are powerful drivers of rumour, speculation and, indeed, humour. Such creations regularly surface in the context of focus group discussions but have rarely been the subject of analysis for what they tell us about relationships and, moreover, the idea of others' relationships. Such an analysis begins to reveal just how powerful these kinds of unknowns actually are in the shaping of responses to new technologies. We are therefore not just dealing with positions, but with responses to positions some of which are known and familiar but others which are unknown and merely imagined. For example, how much do focus group participants really know about the chain that connects Monsanto head office in St Louis to the Indian peasant farmer in Andhra Pradesh? In evoking the character of 'the farmer' we can see how in narrative terms, rural farmers are seen as heroic and as traditional stewards of the land but also as large producers who have been seduced by the promises of a commercial and market-oriented model of agriculture and who are locked into environmentally and socially damaging farming practices. Yet, do middle class focus group participants really know what farmers do on a day-to-day basis? Likewise, NGOs appear one minute as champions of social justice in the face of repressive governments but, at the next, they are the target of cynicism and suspicion because of their links to outside interests which can evade local governance. Scientists can be saviours of the planet but also, just as easily, the makers of monsters.

Underpinning all this – and here, rather bizarrely, I must acknowledge Donald Rumsfeld – are the 'unknown unknowns'. These are the things that will take us beyond what we know we don't know and into the realms of dystopia and catastrophe. In other words, these are dangerous voids to contemplate because with them comes loss of all proportion, familiarity and sense of attachment. It is a truism to say that most things are knowable but not everything can be known by a single individual. Inevitably, living in society means that divisions of labour operate. Certain things have to be taken on trust and on the assumption that others will act responsibly on our behalf (that is, we expect them to know and do things on our behalf). If this trust fails, however, we are left not only with the unknown but with the unknown unknown and its corrosive consequences for human flourishing and progress. For many, thinking about GM and the future of food production invites speculation not just on the unknown but tumbles all too easily into the realm of unknown unknowns.

Transnational research of the kind undertaken for the GMFuturos project draws on multiple perspectives and seeks to undertake controlled comparison. In the end it is an exercise in making a recognisable picture from a very complex set of dots. Inevitably, given the scale of the exercise, there are many dots that remain unconnected (and which will, no doubt, provide topics for future research). A set of connections that I think might usefully be made brings together focus groups, the neoliberal turn and a critique of aspects of the GMFuturos project. It concerns the power of economic interests to confound the things that make the unknown accessible, manageable and acceptable, thereby magnifying the unknown unknown. In other words, a recurrent theme across the examples given in the research was people's sense that there was a degree of collusion between national interests and global science, economics and business when it comes to new technologies – people felt they were being 'kept in the dark' (Macnaghten *et al.* 2010). The scales at which technologies and transactions were being enacted were simply not ones that people felt comfortable working within; they were not available at a 'human scale'.

A fundamental paradox here is the fact that in the countries studied – Mexico, India and Brazil – the neoliberal turn has seen the elimination of the very organisations (trade unions, cooperatives, collectives, land rights movements) that previously provided some command of a 'human scale' and thereby gave voice to those that now appear most marginalised and disempowered in the GM debate. As

Harvey (2007) put it, the essence of neoliberalism is accumulation through dispossession – and here we are not just of talking of material goods but also the loss of culture, organisational capacity, intellectual property, bio-diversity and so forth. These are the very things that securities, ontological and otherwise, have been grounded in for peasant food producers across the globe.

I would suggest that in overlooking a connection to this particular dot, the GMFuturos research is in danger of reproducing an overly linear and ahistorical connection between the macro level (agribusiness) and the micro (the farmer). As a result there is a potential for a kind of erasure which is in danger of replicating the terms of the debate as it is being established by the interests that currently dominate it and which have a vested interest in making relations of production invisible. Thus, for example, in the mass production of food stuffs the dominant pressure of the food industry is on the erasure of the relations of production that underpin the production of cheap food for mass consumption and convenience. Yet, from a number of quarters, there is a counter-move to have these made visible (for example, through labelling, provenance, narratives of origin, fair trade designation, etc.), that is, to reduce unknowns by having the ethics and morality of production written into the act of consumption. These, as Busch (2010) has suggested, are small but important gestures of resistance generated by, and as an alternative to, the neoliberal hegemony. They are also responses that are brought to the surface in the distinctive methodology of 'upstream' focus groups that has been used in this research. By looking beyond individualistic and rather questionable expressions of opinion and attitude, the novel focus group strategy adopted here offers the possibility of understanding how the actual and potential anxieties that come with GM technologies articulate with everyday worlds in which people live.

The question with which this research began was 'Can GM crops feed the world?' In view of the foregoing discussion, one might be inclined to ask 'Which world?' Is it the precarious world of the third world farmer, struggling on the margins of global markets and for whom GM crops are simply one part of a complex mosaic of strategies aimed at surviving until the next harvest? Or is it about feeding the world as it is lived within advanced economies of the north and where appetites draw developing food producers into global food chains. As was discussed at the GMFuturos policy workshop at the Royal Society, this is particularly apparent where vegetable foodstuffs become animal feed needed for the production of meat protein for consumption in the global north (and a similar argument can be made for use of GM crops for the production of biofuels). Depending on which world we are trying to feed, the answers may be very different.

Author biography

Bob Simpson is a social anthropologist whose current research interests focus on bioethics, biomedicine and biotechnologies in developing world contexts. One of the main research settings in which he has explored the encounter between challenging technological developments and local systems of values and beliefs is Sri Lanka. Between 2002 and 2004 he held a Wellcome Biomedical Ethics Fellowship which enabled him to carry out research into the reception of new reproductive and genetic technologies. He is currently work on the ethics of experimentation and the governance of scientific research in Asia through an ESRC/DfID-funded project, Biomedical Health Experimentation in South Asia.

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17

A RESPONSIBLE INNOVATION GOVERNANCE FRAMEWORK FOR GM CROPS

Global lessons for agricultural sustainability

Phil Macnaghten

Introduction

In this final chapter we develop a governance framework for GM crops drawing on insights from the eleven commentaries (Chapters 6 to 16, this volume) as inspiration, and using the anticipation–inclusion–reflexivity–responsiveness (AIRR) responsible innovation framework (Chapter 1, this volume; see also Stilgoe *et al*. 2013) as a lens. Building on Tom McLeish's reading of Latour (Chapter 12, this volume) we argue that a responsible innovation framework is needed to move beyond the sterile arguments of being pro– or anti– the technology, or to confine discussion to the equally sterile territory of risk. The key question concerns conditions. Under what conditions do GM crops offer potential for agricultural sustainability and inclusive development, and are these conditions plausible under real-world circumstances (see Macnaghten and Szerszynski 2013)? Following the AIRR framework, we ask what does and what could a governance framework aimed at better anticipation look like in the light of the commentaries and the GMFuturos research? How could we organise a more inclusive and deliberative framework for governance? What are the opportunities and barriers for more reflexive scientific practices and cultures? And how might we establish more responsive institutional norms and structures for governance?

First, however, it is important to note that all commentators viewed the call to reopen a conversation on GM crops and agricultural sustainability in terms that transcended beyond their risk dimensions as a proposition that was both necessary and timely. The reduction of the governance debate, largely, to the 'risks' of GM crops to human health and the environment, was seen as restrictive and for most, as counter-productive. This is a significant observation. The commentators include many pre-eminent international scholars and practitioners across the crop science, policy studies, science and technology studies and anthropology communities.

The second point that warrants explanation is the rationale for the predominantly British composition of our commentators (all commentators were from British institutions with the exception of Rajeswari Raina who spoke from an Indian context). Even though by definition the commentators represent a geographical sub-set of the global academic community, nevertheless, they remain well-placed to reinvigorate a global debate. The UK was at the epicentre of the GM crop and food controversy in 1998–1999 and its government and research councils arguably led the most sustained and comprehensive response internationally. The resultant initiatives included, among others, the funding of three 10-year Economic and Social Research Council (ESRC) genomics research centres (CESAGEN, EGENIS and INNOGEN), a Biotechnology and Biological Science Research Council (BBSRC) initiated crop science review with a renewed focus on 'public good' plant breeding and on 'the role of genomically-informed but non-transgenic approaches to crop science research' (BBSRC 2004: 6), a well-received report from the Royal Society aimed at stimulating the sustainable intensification of global agriculture (Royal Society 2009), the setting up of a new government biotechnology commission with multiple stakeholders (the Agriculture and Environment Biotechnology Commission – AEBC), the GM Science Review led by the then government's Chief Scientific Adviser Sir David King in 2004, an extensive farm-scale evaluation of three GM herbicide tolerant crops on farmland wildlife (Firbank 2003), and a national public engagement exercise, titled GM Nation? The Public Debate (also in 2004). Many of our commentators have been involved, variously, in the above initiatives over a decade and a half period.

Nevertheless, the particular initiative from which this volume was written was novel in at least three respects. It attempted to draw lessons for governance from a broad-ranging research project, based on the direct ethnographic experience of the views of farmers, publics and scientists. It based its focus of research on three global South settings – Mexico, Brazil and India – three global 'rising powers' contexts that will be of undoubted importance for future debates on agricultural sustainability. And it organised its research effort with the aim of moving the debate on GM crops and their governance, and their potential contribution to agricultural sustainability, beyond the restricted arena of risk. In the remainder of this chapter we reflect on the 11 commentaries and what they mean for the future governance of GM crops for agricultural sustainability.

Anticipation

Anticipation is the first dimension of the responsible innovation framework. An anticipative approach requires the development of capacities to enable researchers and policy-makers to understand the stakes of a technoscientific issue, by systematically exploring possible and plausible futures and their associated societal and ethical dimensions (Guston 2014; Owen *et al.* 2012; Stilgoe *et al.* 2013). Given that GM crop technologies are by now a relatively mature technology, and that at least first generation GM crops have been developed and adopted throughout much of the developed and developing world, an anticipative approach requires in addition a systematic contextualisation of GM crops' social and ethical impacts, as a precondition for imagining how they could be otherwise configured. That is to say, we need a better understanding of the context out of which GM crops developed, of the kinds of social worlds they have contributed towards, and thus, by implication, of how such conditions need to be reconfigured to contribute to more humane, socially just and environmentally sustainable futures. In the words of James Wilsdon (2014: 109), the 'art of anticipation' and associated practices of 'foresight' need to be complemented with a heightened 'sensitivity to the practices of history' and to associated practices of 'hindsight'.

A number of commentators in this volume have highlighted neoliberalism as an important contextual factor to understanding the debate and associated controversies on GM crops. For science and technology studies scholar Les Levidow (Chapter 10, this volume), the development of GM crops in Europe has quintessential origins in neoliberal policy agendas and modes of thought. Reflecting on his role as a long-standing analyst of the institutional dynamics surrounding agricultural biotechnology, Levidow argues that in Europe, a 'biotechnology vision was promoted as an overall solution to the problem of European competitiveness'. This policy narrative, in which 'innovations in the new genetics' were seen as 'foundational to improvements in efficiency and competitiveness', was itself premised on a set of ontological assumptions, fully embedded in European Commission research programmes, in which nature was conceptualised as 'an informational machine whose deficiencies had to be corrected'. Agricultural biotechnology thus became an instrument of a neoliberal agenda, from the mid-1990s onwards, and GM crop technology 'a symbol of anxiety about multiple threats: about the food chain, agro-industrial methods, unforeseen and long-term hazards, state irresponsibility and political unaccountability through globalisation'. Levidow thus adds to the argument developed in the GMFuturos research that there exists an 'institutional void' in the governance of the non-risk dimensions of GM crops (Chapter 1, this volume), arguing that such issues were 'pre-empted by institutional commitments' which had been developed 'to further industrialise European agriculture, to extend proprietary rights to seed varieties and to define "risk" narrowly as the definitive basis of regulation'.

Michael Northcott's commentary (Chapter 13, this volume) develops this argument using the classical Greek concept of *poïesis*, which he defines as 'the unique capacity of humans to generate and sustain aesthetic and ethical ideals through their creative powers on earth'. For Northcott, the 'true makers' are those who utilise the 'grammar of *poïesis*' in the cultivation and making of food especially on their own farms, plots and smallholdings. In this way they develop the intrinsically human potential to 'enhance goodness, truth and beauty' through earth-human interaction. It is this rich contextualisation that he uses to critique the 'gradual neoliberal collectivisation of agriculture by private corporations', which repeats 'earlier collectivisation projects from ancient Egypt to Maoist

China'. Anthropologist Bob Simpson (Chapter 16, this volume) adds a further point. For Simpson, the neoliberal turn 'has seen the elimination of the very organisations (trade unions, cooperatives, collectives, land rights movements) that previously provided some command of a "human scale" and thereby gave voice to those that now appear most marginalised and disempowered in the GM crop debate'.

Anthropologist Penny Harvey (Chapter 9, this volume) sets out further elements of vocabulary to help understand the complex social and ethical relations that 'inhere in and are accompanied by GM crops'. She develops a non-reductionist account of GM crop technologies paying particular attention to the multiple ways in which GM crops are infused with particular 'values, symbolic resonances, aspirations and expectations'. She uses the concept of the assemblage, and an approach that focuses on people's practical activities, to help understand the various ways in which GM crops 'cause problems in people's lived worlds because they are not simply about "food", or rather "food" isn't just about calories' but also 'about family, community, land, farming, cooking, feeding, taste', and where 'the risks are nor simply about "health" in the narrow sense, but about a more general sense of uncertain futures'.

To summarise, we have argued that an anticipatory approach to governance requires sensitivity to the social and ethical impacts of GM crop technologies, which itself requires contextualisation of their use in practice. We have suggested that the link between the development and take-up of GM crops and neoliberalism is one critical element, and that any attempt to reconfigure governance debates will have to reconfigure this relationship. We have argued for the necessity of non-reductionist accounts of the relationship between GM crops and their impacts, which include considerations of the problems GM crops cause in people's livelihoods alongside technical considerations of risk. Good anticipatory practice thus develops out of 'local' cultural and country-specific historical inquiry. In the GMFuturos research, it was the variety of issues and the plurality of narratives that came together in the GM crop and food issue that consolidated the strength of its findings. On this point, Harvey reminds us of the dangers of confining 'the poor to categories not of their own making', including, the John Templeton Foundation question that underwrote its call 'Can GM crops can feed the world', which she suggests is 'perhaps not such a good question', at the least at the level of local practice. While this may be an appropriate question in global spheres of elite policy-making, Simpson (Chapter 26, this volume) asks us to consider 'Which world?': 'Is it the precarious world of the third world farmer, struggling on the margins of global markets and for whom GM crops are simply one part of a complex mosaic of strategies aimed at surviving until the next harvest? Or is it about feeding the world as it is lived within advanced economies of the North and where appetites draw developing food producers into global food chains'.

Inclusion

Inclusion is the second dimension of the responsible innovation framework. To develop responsible governance, the argument goes, requires inclusive and deliberative engagement with a broad range of stakeholders, including publics. In the GMFuturos research, we initiated broad-ranging engagement with publics and smallholder farmers across the three case study sites in Mexico, Brazil and India. Development studies researcher Dominic Glover (Chapter 8, this volume) reflects on the approach and its findings which he sees as a necessary antidote to the narrative that presents the adoption of GM crops in 'rising power' contexts as an unequivocal success story, 'a story of radical and progressive technological change that has been embraced by literally millions of farmers, the great majority of them smallholder producers in the "developing world"'. He highlights how the study counters this narrative: through the finding that both growers and consumers in each of the case settings felt ill-informed about the technology and excluded from decision-making processes; that in the ethnographic field research smallholder farmers evinced little trust in the technical advisors of the extension services; and in the general recognition that the issues at stake in GM crops reflect 'conflicting interests and competing visions [that] are intrinsically difficult to reconcile'. For Glover such findings point to 'a pervasive breakdown in public trust in institutions of science, governance and regulation'.

Science policy researcher Adrian Ely (Chapter 7, this volume) argues that the lack of authoritative governance that GMFuturos found in the governance of GM crops in Mexico, Brazil and India, also pertains to China. Drawing on his own scholarship Ely demonstrates the complex, messy and uneven history of GM crops in China including the ways in which they continue to be constituted by diverse actors as a symbol of wider struggle. He further articulates what is perhaps one of the most complex of challenges, which is how to involve 'citizens of different countries in technology assessment processes and decisions at the international level', while at the same time remaining 'flexible to local problem framings, perspectives and governance contexts'. Levidow adds an element of challenge, namely, how to leave the trajectory of GM crop technology open for public deliberation, including its political-economic setting and agenda.

Notwithstanding such challenges, Bob Simpson reflects on the value of the focus group deliberative methodology as used in the GMFuturos research. While admitting that he is not a big fan of the methodology, nevertheless, he sees its value as utilized in the GMFuturos study as useful and appropriate to opening up 'new kinds of debate, deliberation and participation'. Judith Petts (Chapter 14, this volume) concurs. She sees the GMFuturos research as contributing 'powerful and valuable case studies of how individuals and their social networks respond when faced with an issue that is embedded in complex and novel science'. Reflecting on two decades of research on risk perceptions, she finds a number of convergences that include the power of context, the threat to fundamental values in determining public responses to risk, and the observation that negative responses are more often driven by concerns about 'mucking around with nature' and inadequate controls, than with potential risks to the environment and health. She concludes by pointing to the need for ongoing and longitudinal studies on public and stakeholder engagement, to monitor 'how public debate is developing over time in different social and political contexts'.

To summarise, we have argued that an inclusive approach requires the addition of new voices in the governance of science and innovation as part of a search for legitimacy (Irwin 2006). We have suggested that the lack of inclusive governance, as identified in the three case sites pertains also to China, and contradicts the current policy narrative that presents the adoption of GM crops in 'rising power' contexts as an unequivocal success story. We have further pointed to the significant challenges of promoting inclusive governance that include that of developing ongoing social intelligence through longitudinal studies on public engagement, that of framing deliberative processes so that they open up the trajectory of GM crop technologies to questions of political economy, and that of involving citizens in different countries in decision-making processes at the international level. In addition, there is the added difficulty of how to reconcile what may well be incommensurable narratives and positions. At the end of the day such reconciliation may involve the art of using political judgement in the face of difficult and possibly incompatible choices. However, an inclusive approach to governance provides the grounds to enable plural narratives and framings to come to the surface (including those which tend to be overlooked), to enable deliberation on potentially competing narratives and framings, and to offer novel ways forward should these be forthcoming.

Reflexivity

Reflexivity is the third dimension of the responsible innovation framework, defined, at the level of institutional and scientific practice, as 'holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held' (Stilgoe *et al*. 2013: 1753). Our two commentators from the plant science community, Ian Crute and Keith Lindsey, were asked to reflect on the GMFuturos research and to consider 'what kinds of scientific culture do we need for responsible agricultural innovation'.

For Crute (Chapter 6, this volume), the GMFuturos research reveals valuable findings that side-line the 'worn-out debate about crop genetic engineering technology and its purported consumer and environmental risks', and that alternatively frames the debate about GM crop technology 'in terms of impacts on people's livelihoods, societal values and the sanctity of traditions'. He then proceeds by setting out his own views on what he terms 'crop genetic improvement' technologies: that is, crops genetically improved for yield, quality, disease resistance, nutritional attributes and so on. His views can broadly be summarised as follows: that previous advances in agricultural technologies in the twentieth century (such as F1 hybrid varieties) led to 'spectacular increases in productivity' that 'enabled a 250 per cent increase in the global population (from 1.7 to 6.0 billion) to be fed from only a 40 per cent increase in the area of cultivated land (from 1 to 1.8 billion hectares)'; that if we are to meet the basic needs of 'a future world of at least 9 billion people' and to do so 'securely, sustainably and equitably' we will need further radical agricultural innovation; that the current system of regulation in Europe (where the technology associated with plant breeding is regulated as opposed to the novelty of any derived product) is unnecessary and costly, effectively risking that 'the endeavour of crop improvement will become the preserve of large corporations'; and that plant breeding has a long history of controversy, not least over the vexed issue of ownership, requiring value judgements. He finishes his commentary by setting out what he believes should be the unifying principles to underpin the 'sustainable intensification' of agriculture, which are 'simultaneously to raise productivity, increase resource-use efficiency and reduce negative environmental impacts'.

Lindsey (Chapter 11, this volume) provides a commentary that incorporates a number of Crute's views, including the need for radical future agricultural innovation to 'address the pressing issues of feeding and providing energy for the world in a sustainable manner', and the need for Europe to move from its current system of regulation which is 'arguably disproportionate, expensive and certainly restricts commercialization of badly needed new crops to the very large companies' to a product-based regulatory system of GM crop technologies, which he portrays as 'more future proof'. Lindsey adds a perceptive account of what he terms a 'biological view of the nature of life' within which he situates his own vision of 'the science of genetic modification'. He sets out research on the molecular biology of organisms, which demonstrates how similar genes are between different forms of life, and which has led biologists (himself included by implication) to take the view that 'exchanging genes between organisms is not in itself so bizarre a phenomenon, as in fact many genes have transferred between organisms through the course of evolution'. For Lindsey, GM crop technologies should not be excluded, a priori, as part of a 'broader problem-based solution for ensuring the world is adequately fed', so long as 'that knowledge can prove useful, and subject to the regulatory processes that govern the ethics and safety of biological research'. Lindsey further responds to the findings of the GMFuturos research, endorsing the need to reconfigure 'the way science, politics and society meet to discuss new breeding technologies', questioning whether GM crops inevitably reduce genetic diversity (as claimed in the Mexican case study as set out in Chapter 2, this volume), agreeing that the high cost of regulation for new GM crop varieties mean that 'only multinationals, with very large financial resources, are able to fund this work', and arguing that crops scientists, at least in the UK have 'significantly shifted in their ways to present their ideas to the public – less a case of educating (which is patronising), more a case of explaining their viewpoint and seeking comment'. He further adds that in relation to the assessment of the non-risk aspects associated with GM crops, we may require the establishment of a 'Social Advisory Group in parallel to the existing Scientific Advisory Group, from which Government Ministers could take advice … that could consider the broader issues associated with novel traits or crop/trait combinations, which could feed in to the policy-making process'.

There is a good deal to commend in the commentaries of Crute and Lindsey. Both are coherent and sophisticated examples of what might be described as a crop science 'social imaginary'.[1] In addition, from a responsible innovation framework perspective, we can observe that both commentaries situate the need for GM crop technologies within a public-interest global societal challenges model, both are critical of the increasing role of large multinational corporations in global agriculture (including in research R&D), both accept that the debate should extend beyond science to embrace broader societal values, and both acknowledge the need for new kinds of dialogue and exchange between crop science, politics and society. Nevertheless, the question remains, are they sufficiently reflexive?

Michael Northcott argues that '[m]utual incomprehension between crop scientists and an informed lay food-eating public is a frequent feature of the public debate around GM crops and foods'. No doubt both Crute and Lindsey empathise with such sentiment. However, will their proposed solutions (e.g. changing regulatory frameworks, promoting 'grand challenge' science, embracing consultation, endorsing principles of productivity, efficiency and the environment) help move the debate beyond this 'mutual incomprehension', and towards the inclusive pathways to agricultural sustainability that both desire. Possibly. On the one hand, their appeal to 'public interest' science, alongside their recognition of the hegemonic power of multinationals in global agriculture, is important. As is Lindsey's sophisticated articulation of why GM technology does not appear to be an intrinsically unsettling technology, at least for the crop science community – a conception that undoubtedly is poorly appreciated outside the biological sciences and that requires wider exposure. Nevertheless, as set out by Northcott in his commentary, there remain at least three important limitations in the crop science 'social imaginary' that warrant further explication.

First, there is the argument that the 'relationality between people and land, culture and agriculture, is missed by crop scientists whose primary training is focused on maximising production of an individual crop in a laboratory' (see also Chapter 9, this volume, where Penny Harvey sets out a non-reductionist methodology to understand the impacts of GM crop technologies). This criticism by Northcott is possibly a little harsh, since it is true that in recent years we have witnessed an evolution of interaction between crop scientists and a range of stakeholders, and that such interaction is increasingly seen as welcomed, at least in the UK. Nevertheless, it remains factually correct to say that wider relational activities have been less considered than those delineated by legislative obligations and that a greater appreciation and sensitivity to these aspects is very much 'a work in progress'. Second, there is Northcott's argument that the 'mechanistic and reductionist frame' that underpins much crop science laboratory practice 'underwrites the belief that a laboratory made crop will not influence the environment, the farmers, the eaters and other species who interact with it'. Again, there are important caveats. The crop science community tend to appreciate that GM crops have the potential to influence the environment, and that they are released into the environment as part of an ecosystem that is subject to multiple interactions; otherwise, why is the regulatory system there to protect the environment and human health. Nevertheless, even though environment and health impacts may be considered, albeit within restrictive terms of reference, there is far less attention devoted to societal and cultural impacts, such as those that may reconfigure relations between 'the farmers, the eaters and other species who interact with it'. And third, there is Northcott's argument on political economy. Even through Crute and Lindsey appreciate the dangers of large corporations extending private sector ownership of seeds and crops, which they disapprove, nevertheless, along with their peers, they appear to underappreciate the risks associated with the 'gradual neoliberal collectivisation of agriculture by private corporations', and their potentially long-range impacts on questions of human freedom, dignity and sovereignty.

Physicist and science/theology writer Tom McLeish (Chapter 12, this volume) offers a further element of response. In an alluring commentary, he responds to the fundamental disconnect between science and society, as reflected in the GMFuturos findings, and more widely in the more commonly shared belief that science cannot be trusted to guarantee social progress (see Macnaghten 2010; Macnaghten and Chilvers 2014), as partly a question of narrative failure. Given that the traditional 'modernist-instrumentalist' narrative of science – which presumes that 'science will inevitably lead to enlightenment and social progress', and 'which attempts to restrict the terms of debate to the evaluation and minimisation of technological risk and the maximisation of reward' – is increasingly discredited, McLeish asks how we might cultivate new narrative resources that can promote the 'responsible care' of nature and society in sustainable futures. Using the 'ancient wisdom' literature as a resource, and drawing on a detailed interpretation of the Book of Job, McLeish develops a theology of technology that speaks to an 'ethics of human responsibility' in 'husband[ing] the world', and an 'teleology that centralises and prioritises the wellbeing of the world before the wealth of human beings' (this account is analogous to Michael Northcott's commentary that discovers the concept of *poïesis* across a range of ancient stories, including those of Jews and Christians, as a form of craft that 'enhance[s] goodness, truth and beauty in the given order'). This 'essential rebalancing', for McLeish, is positioned as a response to the tragic tone that informed current responses to GM crop technologies, as evidenced in the GMFuturos study, and as a counter-weight to the crop science's social imaginary that has tended to view genetic modification technologies as 'allowing for the indefinite extension of human intervention in nature'.

To summarise, we have argued that a reflexive approach requires that scientists and policy-makers develop capacities to reflect upon their own commitments and assumptions, to be sensitive to the limits of current knowledge and to be mindful that a particular framing of an issue may not be universally held. We then scrutinised the commentaries from plant scientists Ian Crute and Keith Lindsey. While we found both commentaries coherent, detailed and illuminating, we pointed to some notable latent absences in the dimension of reflexivity that included, the predominant reductionist frame within which crop science laboratory practice takes place, and which minimises appreciation and sensitivity to the potential impacts of GM crops on the relationality that exists between people and land, culture and agriculture; the lack of a narrative response to the commonly shared belief that science cannot be trusted to guarantee social progress; and the lack of systematic engagement with the complex and deeply intertwined relationship that exists between GM crops and neoliberal economics and policy-making.

Responsiveness

Responsiveness is the fourth and final dimension of the responsible innovation framework. To be effective, responsible innovation requires an institutional capacity to change shape or direction in response to improved anticipation, inclusion and reflexivity. Across the three case sites of the GMFuturos study, we found little evidence of a responsive science policy and regulatory regime, a finding that arguably is replicated across most of the developed and developing world, including Europe. The key question is why. As Judith Petts (Chapter 14, this volume) states, reflecting on her own experience, 'why, given all the evidence on the need for new modes of risk governance and public engagement has this largely not happened?'

There are perhaps four intersecting kinds of explanation. First, as argued in Chapter 1 of this volume, there is problem of the 'institutional void' (Hajer and Wagenaar 2003), that is, at least in relation to the non-risk dimensions of GM crops, there are few agreed structures or rules as to how we should govern them. This is an important through obvious point. The further point is why such structures have not been devised. In response to this question, Dominic Glover points to the problem of the 'conflicting interests and competing visions that are intrinsically difficult to reconcile'. Again this is an important point. There is an obvious 'interest' among certain communities (the global seed companies for example, and perhaps certain government ministries) not to open up the debate on the governance of GM crops beyond their risk dimensions, not least because existing commitments are deeply embedded in extant styles of neoliberal policy-making (see Levidow's commentary in Chapter 10, this volume).

Science policy analyst Rajeswari Raina adds a further perspective. She argues that there are institutional rigidities that she identifies in the Indian agricultural science and technology (S&T) system that militate against the possibility of a more responsive and deliberative system. Notwithstanding widespread criticisms, replicated in the GMFuturos study, the Indian S&T system continues to reproduce an industrial model and approach to agriculture, which emphasises increasing yields delivered through the supply of inputs in a centrally controlled linear mode.

Such institutional rigidities help explain the historical lack of participation and transparency in decision-making on GM crops and the inability of the established scientific and political leadership to engage meaningfully with alternative and more inclusive pathways to sustainability. No doubt her analysis can fruitfully be extended beyond India to other 'rising power' settings as well as to the developed world.

In the final section, we outline some modest recommendations for how we might move towards a responsible innovation governance framework of GM crops.

A modest set of proposals

How might we develop a more anticipatory approach to the governance of GM crops? Our modest proposal is to propose an independent, publicly funded and transnational interdisciplinary research programme, with the social sciences and life sciences as equal partners. Such a programme would seek a deeper appreciation of the context in which GM crops have developed in the laboratory and then adopted in the field, from a range of disciplinary and interdisciplinary perspectives. It would also require deeper insight into how ordinary lay people think about GM crops and foods, including in situations when they remain unfamiliar about the technology, and the differential factors that structure responses across different geographical and demographic areas. It would further seek to scrutinise the various and often contradictory questions that tend to preoccupy debates on GM crops and foods, such as:

- Can GM crops can feed the world?
- Do GM crops transgress natural boundaries?
- Do GM crops benefit (large) producers rather than smallholders or consumers?
- Do GM crops impact on biodiversity?
- Do (or could) GM crops operate in the public interest?

In relation to such questions, research would seek to answer: 'What is known?', 'What is not known?', 'What is possible?', 'What is plausible?', 'What if …?' and 'Under what conditions?'. And finally, from such 'thick' understandings, it would explore through methods of foresight, technology assessment, horizon scanning or scenario planning, the conditions under which, if any, GM crops could plausibly contribute to agricultural sustainability (alongside an evaluation of alternatives). Such research would require the participation from, among others, anthropologists, ecologists, ethicists, geographers, linguists, political scientists, psychologists, sociologists, theologians alongside and in partnership with the crop science community.

Responding to the need for improved inclusion in governance, we call for the provision of government-sponsored information, from a range of perspectives and encompassing a diversity of views. We call also for more rigorous implementation of labelling of GM foods, so that at least people are aware of whether they are eating GMOs or not. And we call again for public-funded research aimed at fostering public and stakeholder dialogue, at developing methodological innovation and at improving evaluation and monitoring. Such research should be focused both at national and international levels, be continuous and longitudinal in scope and with a particular focus on global South contexts. It should aim to bring together a broad range of stakeholders, and to use state-of-the-art deliberative methods to explore initial framings and narratives, to inject some new ones, and to move the discussion on in ways that generate inclusivity and common purpose, avoiding logjams while permitting tolerance of remaining disagreements. Such 'action' research initiatives should aim to replicate 'best practice' in dialogue practices, with a particular emphasis on early and intense deliberation, on developing where possible shared definitions of the issues (including their political economy contexts), on ensuring diverse and broad participation (including those which do not represent established interests), on developing support structures that enable participants to develop mature and considered perspectives, and on the need for commitment to ongoing and longitudinal engagement (see also Callon *et al.* 2009 for criteria on classifying good dialogue practices). It would also require structured experimentation to explore how best to involve citizens of different countries in technology assessment processes in decisions at the international level, while at the same time remaining flexible to local problem framings, perspectives and governance contexts.

Responding to the dimension of reflexivity, initiatives are needed to develop and promote more reflexive scientific cultures, particularly in the crop science/ life science community and in policy-making arenas. Building on existing scientific practices of self-referential critique, initiatives are required to help make reflexivity a public matter where scientists and policy-makers are encouraged to develop capacities to reflect on their own commitments, to be mindful of their framing of issues, to be aware of the limits of current knowledge to understand better the legitimacy and complexity of public and stakeholder views on GM crops. Second order reflexivity is also needed where scientists are provided with skills to comprehend the assumptions that underpin their own scientific epistemologies and tacit models of practice (including the ways in which ideas of mechanism and reductionism may be deeply embedded in scientific practice and styles of thought). The development of new curricula and multidisciplinary collaboration and training are also required, alongside the involvement of social scientists and ethicists in scientific laboratories using approaches such as 'midstream modulation' (Fisher *et al.* 2006; Fisher 2007), 'ethical technology assessment' (Swierstra *et al.* 2009) and the systematic reflection of natural scientists on the socio-ethical context of their work (Schuurbiers 2011). Particular emphasis needs to be paid to the training of early career researchers and doctorate students, where ethical and societal training should become embedded in training.

Finally, we need to respond to the dimension of responsiveness, crafting new policy architectures that are designed explicitly to be as responsive as possible. It is pre-emptive to delineate the specifics of a more responsive system and the hurdles that would need to be crossed to realize it. But, most importantly, this would require the development of new institutional structures and norms that are equipped to complement existing regulatory structures that hitherto have relied upon the assessment of risk to human health and the environment as the sole criteria for assessment and decision-making. Building on Keith Lindsey's suggestion (Chapter 11, this volume), this may involve the establishment of new social advisory bodies in parallel to existing scientific advisory bodies, and in addition the use of stakeholder and other deliberative forums, to consider the broader cultural, societal and ethical dimensions of new agricultural technologies (including but not exclusive to GM) and to provide social intelligence to inform good governance. Such bodies would need both to embrace a full range of disciplinary competences, from the social sciences and humanities alongside the natural sciences, and to be equipped to answer and respond to each of the dimensions listed above. Albeit untested (the closest analogy was the relatively short-lived UK Agriculture and Environment Biotechnology Commission; for a critical evaluation see Grove-White 2000) such institutional redesign would be a vital and necessary innovation if GM crops and associated agricultural technologies are to be developed and governed such that they respond to inclusive and socially just patterns of agricultural sustainability.

Our very final recommendation concerns our response to the call from ACRE (2013a, 2013b, 2013c) and BBSRC (2014) to change the system of regulation of GMOs that prevails in Europe from the process model (where regulation is determined by the process used to generate the crop, in this case GM) to a problem-based product trait model (under which plants with novel traits/characteristics, however introduced, are assessed for their safety and environmental impact) as a precondition for responding to the world's food security challenges (for clarification of this argument, see Chapters 6 and 11 by Ian Crute and Keith Lindsey respectively). While we agree with the arguments that the current European system of regulation may not be 'fit for purpose' (i.e. that it is inconsistent, costly and stifling of innovation) we also agree that the proposed 'product-based' system is likely also to be not 'fit for purpose' so long as the regulatory endpoints remain the same (i.e. that they pertain to the effective mitigation of hazards associated with human health and the environment). So long as the broader cultural, societal, ethical and political economy dimensions remain hidden from the regulatory gaze, such initiatives offer little prospect of developing socially acceptable scientific innovation for agricultural sustainability.

Note

1 Charley Taylor defined a social imaginary as 'the ways people imagine their social existence, how they fit together with others, how things go on between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlay these expectations' (Taylor 2005: 23).

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