A **Routledge** FreeBook

PATHWAYS TO SUSTAINABLE AGRICULTURE

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TABLE OF CONTENTS

PATHWAYS TO SUSTAINABLE AGRICULTURE

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Introduction

This is the first in a series of FreeBooks highlighting ten years of work of the ESRC STEPS Centre, with chapters drawn from our *Pathways to Sustainability* book series with Routledge, now numbering nearly 20 books (steps-centre.org/books). The FreeBooks series is part of a commitment to expose the book series to a greater number of readers through Open Access provision, in turn encouraging readers to explore the series further. The opening chapters and the first 30 pages of most of the books are already available online, but here we select a series of other chapters in a specially curated selection highlighting some of the major findings that have emerged over the last decade.

Each book in our series draws on, interrogates and extends the STEPS Centre's 'pathways approach' in different ways. The pathways approach provides an approach to understanding complex and uncertain patterns of system change, identifying how different pathways to sustainability are framed by different actors, and how this influences the diversity of options chosen, what directions are taken, how benefits and costs are distributed and what diversity of options are chosen. Politics is central, shaping knowledge and interests that construct pathways – generating mainstream development paths, while silencing or blocking alternatives. The pathways approach encourages an opening up of understandings and a broadening out of choices, and is elaborated in detail in the book, *Dynamic Sustainabilities*, one of the first books in the series (Leach et al 2010). Across the series, a number of books focus on different dimensions of agriculture and food security, and how they intersect with climate change. Feeding the world, reducing poverty and ensuring that agriculture is sustainable, maintaining ecosystems, while delivering equality and justice is a major global challenge, and is rightly highlighted across the Sustainable Development Goals. Our work asks how such a challenge can be met. How do we improve agri-food systems, while guaranteeing social justice and environmental integrity? We take a critical stance informed by science and technology and development studies, and the intersections between the two, highlighting the politics of knowledge which underpins assumptions about farming, technology and regulatory systems, and the directions of socio-technical change for development, asking fundamental questions about who wins and who loses, and how political economy structures change.

Over ten years, the STEPS Centre has undertaken a lot of work with our international partners on food and agriculture (steps-centre.org/food-agriculture). An early review paper set the term of debate (Thompson et al 2007), while work in Kenya examined the diverse pathways of change associated with growing maize (Brooks et al 2009). Work on the GM controversy highlighted the politics of knowledge and interest at play, and our long-term work is collected together in the STEPS Biotechnology Archive (steps-centre.org/project/biotechnology). A spotlight was shone on the politics of agricultural research in a book on *Rice Biofortification: Lessons for Global Science and Development* (Brooks 2010), and this was pursued in the collection, *Contested Agronomy: Agricultural Research in a Changing World* (Sumberg and Thompson 2012), with several chapters featured in this FreeBook. The changing fortunes of pastoralists in the Horn of Africa were discussed in the book, *Pastoralism and Development in Africa: Dynamic Change at the Margins* (Catley et al 2013), highlighting the changing livelihood pathways emerging under the pressures of market expansion, climate change and population growth in the region.

This collection draws on four books in the series which address three themes central to understanding how pathways emerge in agriculture, and how sustainability is – or indeed is not – generated. The three themes are:

- *framing* (how we understand agriculture and its roles in development),
- *practice* (how agriculture and agricultural research is carried out, and by whom) and
- *governance* (how agriculture is regulated and controlled).

The six chapters in this FreeBook are introduced in the following sections.

Framing

Everyone likes a good success, and development-oriented research is crying out for them. A great chapter in *Contested Agronomy* argues that success-making is an important but problematic practice in framing agricultural research efforts, and hence in defining pathways of development. Chapter 1 in this FreeBook therefore asks: what is success, and how and by whom is it defined? Who is telling the story, to whom and why? How do particular projects – and associated pathways of development – attract attention and so financial and policy support? How this happens is crucial for understanding how pathways are constructed, how power is exerted, and how exclusions occur in the process.

What, then, is success? Very often, outcomes of agricultural research are linked to broad developmental objectives such as poverty or hunger reduction. But there are many routes to this end; and a simple metric related to, for example, potential agricultural productivity or increased nutritional provision from crops or animals may be very limiting. As Amartya Sen long ago argued, simple potential availability is not the same as access: markets, institutions, social relations, and wider politics always come into play. Also, objectives may be broader – such as generating sustainable livelihoods and farming systems – and so not amenable to single indicators; they require a negotiation of both means and ends among different actors. Equally, success may look very different from a gendered angle, or from the position of a younger person or an excluded ethnic group. Such framings of success are inevitably political, and derive from different standpoints. Depending on the position taken, the pathways to sustainable agriculture that may follow – along with the scientific demands, funding flows, expertise requirements – will look very different.

Framing success around expectations – the promise of future gains – is a common strategy in generating stories of success. This is understandable, as individuals and institutions compete for limited funds, but hype and reality may be seriously mismatched. We have seen this of course in the debate about GM crops, for example, long trailed as being able to address a host of major problems, yet having in practice only a limited set of applications. In this chapter, the case of NERICA (New Rice for Africa) is used, and there are many more. Raising funds, whether from venture capitalists or public funding bodies, requires a pitch and a convincing narrative of hope. But too often such narratives define pathways of development, as many get caught up in the excitement, and do not address the very real uncertainties often hidden in the rhetorical claims. This can result in costly and damaging commitments, and the downplaying and underfunding of perhaps much more promising, but less well-backed, alternatives.

Success stories are often framed linguistically in certain ways. The chapter analyses the outputs of the International Food Policy Research Institute's (IFPRI) 'Millions Fed' project, highlighting the way stories are constructed, and the language and metaphors deployed. Military imagery is common – battles have to won, enemies defeated – and victims are always required in a story of success; and plenty of imagery is used of essentialized poor, female, usually African, farmers.

Whatever the definition, success stories require certain types of evidence to support them. The storyline format is crucial, as this constructs a narrative around problem and solution. There are often intense pressures to generate success in development. The whole audit culture around logframe objectives, outcome indicators, and evaluations puts pressure on any scientist or development practitioner to show 'value for money' and impact at scale. This can result in an unhealthy closing down of debate about alternative pathways, of failures and limitations of dominant ones. This may occur through the disciplining of teams, and the setting of limits to fundamental discussion of underlying assumptions and commitments, as well as the selective use of available data.

Chapter 2, drawn from *Adapting to Climate Uncertainty in African Agriculture: Narratives and Knowledge Politics* (Whitfield 2016) explores 'climate-smart agriculture' and its applications in Africa. The linking of agriculture with climate mitigation or adaptation has become an important framing device in recent years, as development efforts attempt to generate triple-wins of increased productivity, reduced climate impacts and poverty reduction. But such framings, as the chapter shows, are very often window dressing, concealing the promotion of a particular technology. The chapter in particular describes the contested nature of evidence from field trials and how incomplete knowledge, with many ambiguities and uncertainties embedded, gets scaled up and promoted, as part of an 'evidence-based' framing of climate smart agriculture.

The chapter illustrates the argument with three cases: NERICA rice, push-pull technologies for integrated pest management, and the system of rice intensification (SRI). It also considers wider platform technologies such as integrated soil fertility management, agroforestry and conservation agriculture. All claim to have triple-win, 'climate-smart' benefits. The chapter argues that translating the ideal suite of technologies to farmers' fields results in a whole set of moves that generate ambiguities and uncertainties. While framed in terms of particular technologies, the realisation of climate-smart agriculture always requires complex, attuned responses, and participatory engagement at the field level, as part of socio-technical innovation processes. While there are nods to this in many programmes, the realisation of genuine, engaged participation in technology development is limited. This is constrained, the chapter argues, by the framing of climate-smartness in exclusively technological terms. There is therefore a need, the chapter concludes, to broaden out approaches to agricultural development to address issues of governance, access, capacities and decision-making, within a framework of empowerment and participation.

As both chapters show, framing thus occurs through a range of calculative devices, embedded in project appraisal, monitoring and evaluation systems, as well as forms of governmentality in project activity that constrains debate and disciplines dissent. A key challenge, as the books from which these chapters are drawn, is to open up debate about success, always posing the questions about the focus of research areas, priorities and methodologies, and defining new measures and metrics that allow a diversity of perspective to have a say. Challenging the organisational arrangements of science and development endeavours to allow a broader, more open approach requires in turn changing practices and rethinking the governance of agricultural development, themes turned to next.

Practice

The practice of experimentation – whether by on-station researchers, extension workers or farmers – is central to agricultural research and development. Chapter 3, again drawn from *Contested Agronomy,* by Harro Maat and Dominic Glover, explores the case of the system of rice intensification (SRI). The case highlights a fundamental disagreement about how agronomic research should be conducted, and so how pathways to socio-technical change are constructed.

The chapter emphasizes the increasing division of labour between accredited scientists who do controlled, replicated and statistically-validated experiments, and extension workers and farmers who do demonstrations, with simple comparisons of treatments, and limited formal analysis. However, despite the differences, both involve a process whereby actor-networks – of people and things – are enlisted into the process of experimentation and demonstration. This happens as much in lab science as it does in field experimentation. Understanding this sociology of science, and its underlying practices in different contexts, is crucial to reveal how 'facts' get established. Yet in agricultural research there is, the chapter argues, an increasing organisational and cultural separation of (lab/station) 'science' and (field) practice. This was not always so – as the chapter illustrates through a brief history of Dutch agronomic science – but today, funding and professional incentives act to generate this disconnect.

It is this divergence of the practice and organisation of science, the chapter argues, that results in the differences seen over interpretations of SRI. Dismissed by lab/station science as 'just good management', it is widely supported by field practitioners, as well as many farmers and scientists embedded in field practice, who make use of an inductive science responsive to local contexts. The SRI network is large and lateral, representing an interesting contrast to the actor-networks of mainstream science and innovation, narrowly centred on established scientists in well-funded institutions.

Thus, as this chapter argues, controversies over agronomy – and the one over SRI has been raging for years – depend on framings, as well as practices of knowledge-making, which are in turn influenced by the breadth and reach of actor-networks and the power relations embedded within them. In other words, the politics of pathways are about how knowledge and practice intersect in different organisational settings: what gets defined as sustainable agriculture will ultimately be defined by such relations.

This is illustrated further in Chapter 4. Drawn again from *Contested Agronomy*, this chapter by Sally Brooks and Sarah E. Johnson-Beebout explores the biofortification of rice, whereby rice grains are enhanced with micronutrients – including zinc, iron and Vitamin A – primarily through breeding programmes. Biofortification requires a combination of scientific skills, encompassing plant breeding, plant physiology, agronomic management, soil science and human nutrition. This chapter focuses on the practices of interdisciplinary engagement that are required by this sort of research, tracing the evolution of the research effort from the mid-1990s.

The 'software' of collaborative practices is emphasized, seen as often more important than the 'hardware' of the separate technological elements. By tracing the research effort over a decade or more, particularly within the International Rice Research Institute, the chapter shows how moments of collaboration have been crucial; for example in opening up debate about the role of environmental factors in combination of genetics, rather just focusing on the breeding dimension. Yet these have been limited, and much of the work remains compartmentalized. The explanation links again to the practices of science. Opportunities for opening up to interdisciplinary interactions occurs, the chapter argues, among early career researches, unburdened by professional expectations and funding requirements. But this is often closed down, as the work develops by routines and incentives that constrain interactions, despite the outward rhetoric. The chapter discusses the HarvestPlus programme of the CGIAR and the Global Rice Science Partnership, both presented as efforts that bring together different types of scientific expertise for the global public good, focused as they are on major public health and development issues. Yet the practices of science in both instances act to narrow the focus of research, excluding for example social or political issues, as well as also many technical questions.

Both Chapters 3 and 4 show how by narrowing the scope and constraining the practices of science and technology development, the opportunities for contestation, dispute, scepticism and challenge – supposedly the hallmarks of good science – are constrained. This limits pathways for scientific and technological development, constraining the diversity of options for meeting vitally important challenges, such as providing safe, cheap and nutritious foods to poor people.

Governance

Chapter 5, 'Rethinking regulation', is drawn from the book *Regulating Technology: International Harmonization and Local Realities* (van Zwanenberg et al 2011). It explores the regulation of genetically-modified cotton seed in China and Argentina. The chapter shows how global, national and local regulatory pressures combine to influence socio-technical pathways, with quite different outcomes. The chapter examines how harmonizing regulatory norms emerging out of international regulations compare, contrast and interact with socio-technical practices of poor users of technologies in particular places. It highlights the limits of local governability, despite global norms.

For example, regulation fails to reassure farmers in China that seed is of good quality.

This is not just because of poor implementation and lack of capacity, as is usually assumed. It is more fundamentally about mismatches between regulatory governance regimes. International regulations, as interpreted by national regulators, focus on risk governance, framed in a particular way. National regulatory systems are of course keen to ensure market access and so comply with globally defined regulatory norms, in attempts to create harmonized systems, and so attempt to implement these, with varying success.

Regulatory systems therefore help to construct pathways. Attempts at globalized harmonization, for example, support a particular pathway of agriculture, dominated by proprietary technologies, owned very often by large companies, sometimes with transgenic GM technologies (for example Bt cotton) as a central element. The result is that regulatory governance acts to push a structural change in the seed sector, and agriculture more broadly. In the case of Argentina, socio-technical pathways are seen to support the innovation capacities of large, often multinational companies and large-scale farming, at the expense of smallholder alternatives. By contrast, in China, there has been more of an attempt to support small-scale production, but within a clearly-defined technology pathway, again supporting GM cotton, with the support of both private and public sector companies.

But such regulatory regimes, emerging from international norms, and influenced by large-scale commercial interests, do not always chime with local socio-economic realities. Seed regulation in Argentina occurs only in formal markets, and so benefits only larger farmers. Informally marketed seed, the majority of which supplies smallholder farmers, is outside the reach of regulation. Instead local practices act to 'regulate' seed quality, but under more improvised, informal systems of governance. In China, farmers and agro-dealers attempt to address challenges of the lack of information about seed quality and try to improve the reliability of seed supply to smallholders. These challenges lie outside the ambit of the formal system, but informal regulatory practices emerge in markets and supply chains instead through local practices and institutions.

There is therefore a mismatch between international regulatory approaches, as adopted by national governments, and local practices, meaning that regulation is partial, and restricted only to certain markets and farmers. Rethinking regulation, the chapter which concludes the book argues, requires the negotiation of norms across local, national and international contexts, opening up regulatory institutions to the views and perspectives of poorer users. This needs to occur in ways that acknowledge dynamics, complexities and diverse framings of different groups. In turn, this requires the balancing of regulatory state interventions with deep understandings of contextual issues on the ground.

Drawing on lessons from GM crops globally, the book *Governing Agricultural Sustainability* (MacNaghten and Carro-Ripalda, 2015) suggests a framework for addressing these complex governance questions, in order to facilitate more inclusive, just and equitable pathways to agricultural sustainability. Drawing on research carried out in Brazil, Mexico and India, and responding to a series of commentaries, the book's final chapter (Chapter 6 in this FreeBook) aims to move beyond the unhelpful arguments about being pro- or anti-GM technologies to thinking about a framework for responsible innovation governance.

There are four elements to this: anticipation, inclusion, reflexivity and responsiveness. *Anticipation* requires thinking about possible futures, and embracing ambiguities, uncertainties and indeed ignorance, and not limiting the debate to 'risk', where probabilities of known outcomes can be defined. Much debate about socio-technical futures in agriculture has been closed down by a neoliberal framing, and by the political economy of domination by certain interests in agricultural development. The studies find a lack of *inclusive* governance in all settings. Opening up to debates to wider social and ethical concerns, including those not framed by 'global' discourses, is essential, the chapter argues. To do this requires inclusive and deliberative engagement by diverse stakeholders and publics, allowing plural narratives and framings of agricultural futures to emerge, and in turn helping to instil trust in public institutions and policy-making. *Reflexivity* requires scientists, policymakers and publics to reflect on their own commitments and assumptions, interrogating the social, ethical, moral as well as scientific basis of the 'social imaginaries' projected in their proclamations about the future, and what constitutes the highly contested notion of sustainable agriculture. This must involve accepting the limits of current knowledge, and the fact that viewpoints on technology futures are rooted in more than just scientific understandings, which link people and land, culture and agriculture. Finally, *responsiveness* highlights the need for innovation systems to change shape and direction. This points to the politics of governance, and why incumbent institutions and interests may prevent this, framing problems and solutions in particular ways, or asserting commercial and political commitments to certain technological pathways.

As Chapter 6 concludes, if cultural, societal, ethical and political economy aspects are excluded from governance – including risk regulation of new technologies – then the prospects of promoting pathways towards sustainable agriculture of wide benefit will remain elusive. Across the chapters in this FreeBook, and in the work of the ESRC STEPS Centre more broadly, this is a recurrent message, requiring a politics of sustainability to be central to collective efforts to make a more sustainable, equitable and just agriculture and food system for all the world's people.

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CHAPTER 1

Success-Making and Success Stories

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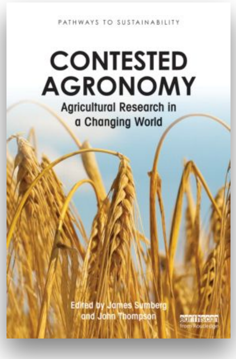

Learn more:

Agronomic research in the spotlight[1]

James Sumberg, Robin Irving, Elisabeth Adams and John Thompson

Introduction

> But the question is whether Africa has the technologies that can do this [allow the 300 million Africans living on less than a dollar a day to produce food, generate incomes, employment and higher savings]. The answer is a resounding yes. The International Food Policy Research Institute (IFPRI) in its book *Successes in African Agriculture* says Africa has developed technologies with transformative potential for turning around the fight against hunger.[2]

Over the past decade or so there has been much interest in the gathering, analysis and telling of 'success stories' about agriculture and agricultural development in sub-Saharan Africa (SSA) (see special issue of *International Journal of Agricultural Sustainability* 2011, 9(1); also Tiffen et al 1994; Snrech 1995; Dijkstra 1997; Roper 1999; Wiggins 2000; Uphoff 2002; Gabre-Madhin and Haggblade 2004; Mortimore 2005; Wiggins 2005; Baffes and Baghdadli 2007; Reij and Smaling 2008; Jacovelli 2009; Spielman and Pandya-Lorch 2009b; Haggblade and Hazell 2010; Pretty et al 2011).[3] The websites and publicity materials of development actors ranging from international funders to local NGOs feature hundreds of agricultural success stories.

At one level the interest in success stories can be understood as part of the larger 'development fight-back', an effort to change negative public perceptions of Africa and of development assistance more broadly. The focus on success stories also links directly to ongoing academic and policy debates around aid effectiveness (Bourguignon and Sundberg 2007) and impact evaluation (Ravallion 2009), as well as the role and importance of development narratives within policy processes (Roe 1994; Keeley and Scoones 2003). At another level, success stories are also one of the ways that research and development organisations justify their existence and seek to secure larger budget allocations in an increasingly competitive funding environment.

It is important to note that the recent interest in success stories about African agriculture coincides with the apparent movement of agriculture up the public policy agenda (de Janvry and Sadoulet 2010).

Wiggins (2005) provides an analysis of the lessons that can be gleaned from success stories about African agriculture, stories generated either through the synthesis of published case studies (Turner et al 1993; Snrech 1995; Wiggins 1995; Wiggins 2000) or through the nomination of individual cases (Gabre-Madhin and Haggblade 2004). The focus of Wiggins' analysis is on what the stories say about the factors required to achieve successful agricultural development: for example, the need to reduce transport costs; the need for institutional innovation in agricultural supply chains; and the need for a better understanding of markets and market failures. On the other hand, he says little about the stories themselves.

In this chapter, our focus is on the stories as opposed to the underlying research results, technology, change, 'progress' or 'success' that they describe and (in some cases) attempt to explain. We are not setting out to evaluate the validity of particular success claims, but rather to understand why and how such claims are constructed and promoted. Ultimately we seek to throw light on the dynamic between success stories and agronomic research.

The act of styling a project, programme or experience a 'success' and communicating this through a story draws attention to two closely related sets of questions: What is success, and how and by whom was it defined? Who is telling the story, to whom, how and why? Addressing these questions creates the basis for an analysis of the politics around development success stories. By exploring the proposition that these 'good news stories' must be read as innately political, it is not our intention to be churlish or reinforce the stereotype of inward-looking, complexifying, success- denying academics. Rather, we want to use the burgeoning interest in success stories about agriculture in SSA to open up a more nuanced consideration of how the results of agronomic research are used within public policy processes, and the implications of these dynamics for agricultural research, agricultural development and rural livelihoods.

Two common sayings draw attention to the politics of success. The first, '*Nothing succeeds like success*', suggests that success reproduces itself, or in other words, that it is possible (and obviously desirable) to enter into a virtuous circle of success. If this is so, then there should be a strong motivation for claiming success and by doing so, placing oneself within the virtuous circle. The second saying, '*Success has many parents but failure is an orphan*', highlights the idea that given such a strong motivation, the competition to be associated with success is keen. With so much at stake, it should not be surprising that parental claims to particular successes can be strongly contested.

The argument we make is that in the realm of African agriculture (and more broadly within development), success stories are becoming an increasingly important instrument in the competition for policy attention and financial resources. We also argue that these success stories are becoming integral to policy processes: they legitimise new kinds of 'evidence', and because of their story format, that evidence can be particularly potent. As a result, success stories are playing an important role in the tactical dynamics within agricultural policy processes, allowing actors to breathe new life into their advocacy for particular policy positions. Again we want to emphasise that we are in no way disputing the proposition that agronomic research has delivered significant and tangible benefits to (some) farmers in (some parts of) SSA, as well as to consumers, food processors, national economies and so on.

The remainder of this chapter is organised in four sections. The next section explores the meanings of success. Then we present a simple theoretical framework for understanding the dynamics of 'success making'. Following this, we examine these dynamics primarily through the success stories generated by the Millions Fed project. The final section discusses some implications of this analysis for agronomic research in Africa.

Defining success

Success is the achievement of a good or desirable outcome, and a successful project, technology or policy is one that contributes to that outcome. For most people involved in agricultural development, reductions in the incidence of hunger and poverty are good and desirable outcomes. Similarly, most would consider growth of the agricultural economy, increased rural incomes and productivity gains as desirable outcomes. Along these lines, in his consideration of agricultural success stories from SSA, Wiggins (2005) defined success as periods of sustained agricultural growth. Similarly, for the Millions Fed project, Spielman and Pandya-Lorch (2009b) measured success in terms of feeding additional people and eliminating hunger.[4]

However, for some observers of rural development, the notion of success is open to interpretation, manipulation and contestation. The work of David Mosse (2004a, 2004b) probably best exemplifies this approach, with success being actively produced, constructed and reconstructed by, and to meet the evolving needs of, individuals, implementing organisations, local officials and funders. Mosse's analysis of his 10 years of engagement with the Indo-British Rainfed Farming Project led him to a definition of success that is unlikely to be to everyone's taste: to 'conceal ideological differences, to allow compromise and the enrolment of different interests, to build coalitions, to distribute agency and to multiply criteria of success within project systems' (Mosse 2004b). But are these two approaches to success really so far apart? We don't have to be card-carrying post-modernists or social constructivists to accept the proposition that in any particular situation there will likely be some ambiguity and contestation around the meaning of success. An acknowledgment of social difference and a nuanced, multi-dimensional understanding of poverty demand an equally nuanced, multi-dimensional understanding of success; and there are legitimate differences of opinion regarding the weight that should be given to the different dimensions. Thus there will be winners and losers associated with every development intervention, no matter how strong or well articulated its claims to success. The differential impacts of 'successful' technical change within agriculture are an important theme of feminist and gendered analyses of agriculture in SSA (Stamp 1989; World Bank et al 2009).

It is also important to remember that in the world of agricultural development it is appropriate to see success as both emergent and contingent, which means that claims of success must be re-evaluated in the light of changing circumstances. For example, while the 'maize revolution' in Zimbabwe in the early 1990s was repeatedly declared a success (Eicher and Rukuni 1994; Eicher 1995), seen from the vantage point of 2011, following a decade of political and economic chaos, the meaning and significance of this particular success must surely be re-examined. Sara Berry (1993) reminds us that in rural SSA, 'no condition is permanent', to which we must add 'even success'.

Finally, any consideration of success must also take failure into account. Here we suggest that, from a development perspective, 'learning' should be one of the 'good and desirable' outcomes associated with every policy, initiative or project. It is undoubtedly true that successful learning does not require broader project success: a project that fails to deliver on any of its main objectives may nevertheless provide invaluable learning (and other unanticipated benefits). Fenichel and Smith (1992) refer to these as 'successful failures'. For example, in his analysis of the disastrous Niger Agricultural Project in Nigeria, Baldwin (1957) clearly and systematically highlighted the importance (for future projects) of recognising and making full use of the detailed agricultural and environmental knowledge of local people. If this 'learning' had fallen on fertile ground at the time (in fact it took another 25 years to germinate), the cost of this 'failed' project would have been repaid many times over. Does a single-minded focus on the demonstration and celebration of success, which incentivises a dynamic of 'success making' (and the burying of all that cannot easily be construed as success), significantly reduce the opportunity to learn and benefit from 'successful failures'?[5]

Success making

In this section, we introduce a simple theoretical framework for understanding the process and dynamics of 'success making'. Drawing from securitisation theory in the field of international relations (Taureck 2006), we suggest that success making is first and foremost a speech act: simply by proclaiming 'success' something is being done. In other words, labelling something a success is a critical first step in the construction of a success story. Success making requires a 'success maker', an actor who is motivated and able to proclaim a particular project, programme, innovation, technology, policy or organisation a success. By proclaiming something a success, the success maker initiates a process that in time may shelter the claim from normal scrutiny and critical evaluation (although in some cases this may backfire and instead draw increased attention to it). As outlined here, success has no objective meaning, and claims of success do not arise through an objective process of evaluating results, outcomes or impacts. Rather, success is what the success maker says it is, what he or she can make stick. Success stories are an integral element of success making.

We hypothesise that the main driver of the recent spate of success making is the increasing pressure on development actors at all levels to demonstrate results, effectiveness, impacts, value-added and/or 'value for money' in order to justify their existence and continued finanical support. We also hypothesise that there are two further conditions that lend themselves to high levels of success making. First, when the desired outcomes are complex and/or expected to emerge over the long term (e.g. 'sustainable rural livelihoods'; 'sustainable farming systems'; 'climate-resilient cropping systems'; or 'empowerment') and it is therefore difficult to identify meaningful and measurable outcome indicators. Second, when an organisational imperative is such that it swings the communications balance towards simple, compelling messages at the expense of nuanced or critical analysis.

Not all attempts at success making yield the desired result, which in the first instance is the widespread recognition of the particular project, technology or programme as a success. We hypothesise that attempts at success making are more likely to gain traction in cases where the proclaimed success is framed in a way that does not challenge mainstream thinking and sits comfortably within a dominant narrative; and where the success story is told in a simplistic way and promoted using a range of easily accessible media.

Like researchers all over the world, individuals and organisations involved in agricultural research have long sought to create an air of expectation around particular lines of research. The agronomic literature from SSA is full of claims that particular technologies, often still at the experimental stage, are 'promising' or have 'potential': examples include alley cropping (Kang et al 1981); black sigatoka-resistant plantain (Vuylsteke et al 1993); fodder legumes (Tarawali 1994); organic matter technologies for soil management (Snapp et al 1998; Fischler et al 1999); agricultural biotechnology (Wambugu 1999); conservation agriculture (Fowler and Rockstrom 2001); and vegetable soybeans (Chadha and Oluoch 2004). The incentives to present research findings in the best possible light are clearly long-standing, yet claims such as these can be seen as a first, tentative step in a process of success making.

Orr et al (2008) used the case of NERICA rice to explore some of the dynamics of success making identified above. The name NERICA was derived from the phrase 'New Rice for Africa': selected following a process of inter-specific hybridisation, these varieties have received much media attention and are now being heavily promoted in rice growing areas of SSA. In tracing the origin of claims made about the agronomic characteristics, performance, spread and impacts of the NERICA varieties, Orr et al showed that the making of success claims began very early in the technology development process, so that most of the initial claims were based on data that were at best preliminary and limited. Through repetition (by WARDA)[6] and propagation (by WARDA's funders, partners, development-oriented news sites, etc) these early claims became deeply embedded in both narratives about NERICA and the World Wide Web. Orr et al concluded that, even as a more nuanced picture of the performance characteristics and potential of these varieties began to emerge, the continuation of this dynamic suited WARDA, as the simple story line, accompanying publicity and international accolades[7] helped buttress the organisation's precarious financial position. Perhaps not surprisingly, these conclusions were contested by WARDA (Wopereis et al 2008).

Over the past decade, interest in the potential for 'scaling up' and achieving 'impact at scale' – despite the acknowledged importance of location specificity and Wiggins' conclusion that developments in African agriculture have generally been 'a cumulative effect of a series of quite small improvements for any given crop or locality' (Wiggins 2005: 18) – have changed the game for all development actors. Specifically, the need for ever more impressive success stories, combined with new communications opportunities, has super-charged the dynamics around, and the implications of, success making.

Writing success

Success stories about African agriculture fall into two broad categories. In the first are stories that are told primarily for non-specialists, but also speak to policy makers. These include some outputs from the recent Millions Fed project (Spielman and Pandya-Lorch 2009a) as well as the hundreds of stories that appear in the publicity materials and websites of bi- and multi-lateral funding agencies, research institutions, continent-wide initiatives, NGOs and agri-business companies.[8] Some common features of this genre of success story include simplified language; general descriptions and overviews often formatted as summaries or highlights; the use of compelling images; and a dissemination approach that draws on a marketing 'push strategy' (Hair et al 2009: 413), where demand for information is created through broad promotion and accessibility.

The second category includes success stories that are primarily for professional and academic audiences, and where the policy messages are more explicit (Tiffen et al 1994; Dijkstra 1997; Uphoff 2002; Gabre-Madhin and Haggblade 2004; Mortimore 2005; Baffes and Baghdadli 2007; Reij and Smaling 2008; Spielman and Pandya-Lorch 2009b; Haggblade and Hazell 2010). The (largely) internally generated results demonstrating high returns to investment in CGIAR research could also be seen as falling within this category (e.g. Plucknett 1991; Collinson and Tollens 1994; Maredia and Eicher 1995; Maredia and Byerlee 2000; Zeddies et al 2001; Alene et al 2009; Alene 2010; Nalley et al 2010). Some common features of these success stories include language that is acceptable and popular within particular academic and professional communities; an emphasis on the application of an established or emerging theoretical or conceptual framework; dissemination through a means or media that is respected within the community (a peer-reviewed journal or professional publication) and that often has restricted accessibility; and a dissemination approach that builds on a marketing 'pull strategy' (Hair et al 2009: 413) where the audience is more engaged in a process of seeking out new information. Related to this second category is a small body of work aimed at academic and professional audiences that explores failure (e.g. Baldwin 1957; Hogendorn and Scott 1981; Webb 1991; Gibbon 1992; Filipovich 2001; Orr and Ritchie 2004; Zoomers 2005).

An important recent initiative to identify and disseminate success stories about agriculture was the Millions Fed project. Millions Fed was designed to 'assess the evidence on what works in agriculture' (Spielman and Pandya-Lorch 2009b: vii) in an effort to leverage initiatives to address issues of hunger and malnutrition. The project was initiated and funded by the Bill & Melinda Gates Foundation (BMGF), which approached the International Food Policy Research Institute (IFPRI) to 'examine successes in agricultural development and draw out the lessons they offer' (Spielman and Pandya-Lorch 2009b: vii). A few years earlier, BMGF funded a similar project – Millions Saved: Proven Successes in Global Health (Levine 2004, 2007) – in partnership with the Center for Global Development.

Drawing on the work of Gabre-Madhin and Haggblade (2004) and Levine (2004, 2007), Spielman and Pandya-Lorch (2009b: 154) developed a methodology for the Millions Fed project with the objective of selecting 20 case studies representative of 'relatively large-scale and long-term success … backed by strong evidence of positive impact'. This involved a global 'call for nominations' that drew on case submissions, suggestions of experts and desk research. With over 250 nominations, the project team sorted the cases according to two qualifying criteria (that the intervention had been conducted in at least one developing country; and that the intervention related to agricultural development directly) and three primary evaluative criteria (relevance to improving food security among vulnerable groups; a scale appropriate at least to the national level; and implementation within the past 50 years). Additional evaluative criteria relating to proven impact and sustainability were also considered, but in a more informal manner to allow consideration of non-traditional evidence. A final set was compiled of 20 stories (five relating exclusively to SSA) – each drawing on a synthesis of multiple sources including first-hand accounts and impact assessments – and an overview of general lessons learned, including what worked and why.

A strategic communications package was produced by IFPRI to disseminate the stories. A primary output was the book titled Millions Fed: Proven Successes in Agricultural Development (Spielman and Pandya-Lorch 2009b), which features an opening overview chapter, 20 chapters profiling the individual success stories, and several appendices relating to methodology and references. This 184-page publication is glossy, colourful and attractive, containing many photographic images. However, some of the stories have enough data and technical detail to put them beyond a general readership.[9] Thus this book straddles the two categories of success stories identified above: some parts appear to be primarily for non-specialists, but others would present a challenge to this group. It is available only in English.

A smaller booklet version, *Highlights from Millions Fed*, was also produced (Spielman and Pandya-Lorch 2009a), in addition to an 11-minute video.[10] In the booklet, the success stories are presented in relatively little detail and are grouped under six headings, including 'Intensifying staple food production', 'Integrating people and the environment' and 'Expanding the role of markets'. The booklet then addresses two questions – 'Why did it work?' and 'What can we learn?'– and ends with a section titled 'Looking ahead'. In an appendix titled 'Case studies', a brief summary of each success story is presented; the summaries for the three stories having a link to agronomic research in SSA are reproduced in Box 11.1. In terms of the level of technical detail and overall presentation, it is fair to conclude that *Highlights from Millions Fed* and the accompanying video are meant primarily for consumption by non-specialists. They nevertheless promote more or less explicit policy messages. The 24-page booklet is available in English, Spanish, simplified Chinese, French and Hindi.

The Millions Fed outputs were presented at 'book launch events' in Nairobi, Dhaka, Seattle, Addis Ababa and Washington, in which audiences were provided opportunities for questions and dialogue relating to the project and agricultural development more generally (IFPRI 2009). Additional communications outputs of the project include online content within IFPRI's website, and various media and public relations tools. In August 2010, the Millions Fed book was awarded the Quality of Communications Award by the Agricultural and Applied Economics Association (IFPRI 2010).

Box 11.1 Case studies from Highlights from Millions Fed with a link to agronomic research in SSA (source: Spielman and Pandya-Lorch 2009a: 18–19).

Breeding an 'Amaizing' crop: improved maize in Kenya, Malawi, Zambia, and Zimbabwe

Melinda Smale and T.S. Jayne

Key Period: 1965–90

Geographic region: Kenya, Malawi, Zambia, Zimbabwe

The intervention: Sustained investments in innovative breeding programs, dedicated scientists, and supportive public policies drove the development and spread of more productive maize that translated into better livelihoods for mil- lions of farm households. By expanding access to modern (improved) maize seeds among smallholder farmers, yields multiplied several-fold and contributed significantly to improving food production and food security in the region. While the fiscal burdens of state-led marketing and credit policies rendered the growth unsustainable, by 2000–2005, maize, most of it modern maize, covered more than three-quarters of the land under cereal cultivation in the four countries.

Resisting viruses and bugs: cassava in sub-Saharan Africa

Felix Nweke

Key period: 1971–89

Geographic region: Sub-Saharan Africa

The intervention: Two major control programs were designed to combat serious threats to cassava production in Sub-Saharan Africa – the cassava mosaic dis- ease and the cassava mealybug. These programs played a critical role in raising cassava yields beginning in the 1970s, turning cassava into a cash crop that is now spreading throughout Africa. In the early 1970s, the introduction of bio-control strategies to destroy mealybug infestations reduced yield losses by 2.5 tons per hectare. In the late 1970s, the introduction of improved, disease- resistant varieties controlled cassava mosaic disease while contributing to yield increases of 40 per cent. These two programs played a particularly critical role in countries such as Nigeria and Ghana, and have contributed to improvements in food security for at least 29 million people.

Re-greening the Sahel: farmer-led innovation in Burkina Faso and Niger

Chris Reij, Gray Tappan, and Melinda Smale

Key period: 1980–present

Geographic region: Burkina Faso and Niger

The intervention: The rediscovery and diffusion of traditional agroforestry, water, and soil management practices in Burkina Faso and Niger has trans- formed large swathes of the region's arid landscape into productive agricultural land. In Burkina Faso's Central Plateau, the rehabilitation of between 200,000 and 300,000 hectares translated into roughly 80,000 tons of additional food per year, enough to sustain about half a million people in the region. In southern Niger, farmer investments in agriculture are estimated to have transformed approximately 5 million hectares of land, improving food security for at least 2.5 million people.

Reading success

First reading

The seven chapters of the *Millions Fed* book focusing on SSA, while reflecting some diversity in their internal organisation (as reflected in the non-uniformity of sub-headings), are distinctly structured in a chronological narrative scenario format that features discussion of a problem, the solution and the successful results (Roe 1994). Although less explicit than in the opening chapter, the individual chapters also contain a call to action, which is most often embedded within the solution or results section of the narrative. The Millions Fed booklet features the same headings and sub-headings as the opening chapter of the book, with the exception of a section in the book titled 'Caveats', which offers several qualifications relating to the successes outlined.

Key vocabulary within the titles of the success story chapters reflects a strong military or battle reference. Title words include fighting, enemy, unlocking, conquering, resisting and navigating. The use of words such as these can serve as signifiers reflecting a cultural construction that links military references to crisis, mobilisation and a call to unified action (Eisenburg 1984).

The covers of both the book and booklet feature two horizontal bands of images. The top band is made up of six close-up images of people's faces. The subjects of these six images are diverse in terms of gender, age, ethnicity and dress. As argued by Deacon et al. (1999), the informal composition of images like these – reflected in the different image angles and backgrounds – could be seen to suggest familiarity. The subject of each image makes direct eye contact with the camera, which from a Western cultural perspective signals equality of status and personal connection (Deacon et al 1999: 194).

The bottom band of the cover features images of food items that have been blurred through image enhancement. These cover images, as iconic signs that resemble what they represent, help to anchor the issues of people and food as key themes of the book and the booklet.

Women feature in a high proportion of the images in the opening chapter of the book, as well as in those in the seven chapters relating directly to SSA. Of the 40 images in total, 23 feature people as their primary subjects.[11] Of these images, 13 depict only women, seven feature only men, and three depict men and women together. The preference for images featuring women is even more evident in the booklet, where nine of the ten internal images that feature people have women as the subject.[12] This could reflect an acceptance of the dominant narrative which suggests that women are particularly vulnerable to poverty, hunger and malnutrition; play a significant role in smallholder and subsistence farming; yet have generally been neglected by agricultural research and development (World Bank 2007a). At the same time, the high proportion of images depicting women in Millions Fed might prompt a reader to conclude that women are the key benefactors of the successes outlined.

In the 17 images in which people's facial features are identifiable, they are all either smiling or looking content or focused. Within the field of social psychology, these types of facial expression tend to be considered symbolic of happiness, enthusiasm and progress (Rashotte 2002). In all but one of the SSA success story chapters, there is at least one image, often prominent, that depicts action or movement.[13] It is also of interest that the majority of the images depicting people (23 in total) tend to focus on an individual or apparent household group (15) rather than larger or mixed groups (eight). It could be argued that these images are in line with a policy narrative that emphasises the significance of individuals, particularly women, taking action individually or in small family groups to increase their agricultural productivity.

In summary, the African success stories in Millions Fed are based on a linear or process model of communication (Fiske 1990); are closely aligned with dominant narratives about agriculture in SSA and how the challenges it faces should be addressed; and use photographic images to try to create a personal, if not emotional, link to the reader. The main message in these stories is that while African agriculture faces many problems, rigorous analysis of the evidence shows that these challenges can be successfully overcome through investment in the right kinds of research and development activities.

Second reading

As noted above, Millions Fed built directly on work by Gabre-Madhin and Haggblade

(2004), in which experts were surveyed in order to identify 'emerging successes' in African agriculture. This study was published in the highly respected World Development journal, and earlier as an IFPRI discussion paper (Gabre-Madhin and Haggblade 2003) – both very much oriented toward academic and professional audiences. There are also crossovers between Millions Fed and the 2010 monograph Successes in African Agriculture: Lessons for the Future, edited by Steve Haggblade and Peter Hazell (2010), which is also aimed at professional and academic readers.

There are several important linkages and commonalities between these efforts to identify and publicise success stories. First, the World Bank and IFPRI were central to all three, and individuals working for or closely associated with these organisations played major roles in project conception and management, the associated research, writing case studies, and editing and producing the collected stories. Second, all put considerable emphasis on using 'evidence' and 'rigorous analysis' to identify 'what works' and 'lessons' that will lead to 'sound agricultural investments' and ultimately poverty and hunger reduction. Finally, one is struck by the degree to which a limited number of examples – maize breeding, cassava pest control, soil fertility management and small-holder cotton production – are fashioned and refashioned as success by the different studies (Table 11.1). On the other hand, some other examples, such as adaptive on-farm breeding of bananas and increased rice production in Mali, have not been re-used to the same degree. Did they not stand up to close scrutiny and rigorous analysis, or were they deemed less amenable to the simple messaging inherent in the success story format?

In the earlier presentation of the success making framework, a number of hypotheses about the factors associated with this process were identified. Here we return to these and ask: What is driving the dynamic of success making that we argue is discernible in efforts such as Millions Fed and Successes in African Agriculture, and why do the different actors contribute to and engage with this dynamic in the ways they do?

Historically, the World Bank has been a major funder of agricultural research and development activities in SSA, both through national governments and via the CGIAR. While the priority given to agriculture has declined over the past decade, there is some indication that agriculture is moving up the policy and funding agenda (de Janvry and Sadoulet 2010). However, some World Bank activities in agriculture have been heavily critiqued (e.g. Harrigan 2003; Fortin 2005), and the Bank's own evaluations of its agricultural investments in SSA make sobering reading (World Bank 2007b, 2010). Given this record and the difficulties of reducing poverty and food insecurity in SSA, the Bank must be under ever-increasing pressure to demonstrate positive impact from its strategy of investing in agricultural growth via market reform and liberalisation, technology development and infrastructure. With the exception of the 'Re-greening the

TABLE 11.1 Recycling of a small number of success stories

Example	*Successes in African Agriculture* (Gabre-Madhin and Haggblade 2004)	*Millions Fed* (Spielman and Pandya-Lorch 2009a, 2009b)	*Successes in African Agriculture* (Haggblade and Hazell 2010)
Maize breeding	Maize breeding	Breeding an 'Amaizing' crop: improved maize in Kenya, Malawi, Zambia, and Zimbabwe	'Seeds of success' in retrospect: hybrid maize in Eastern and Southern Africa
Cassava pest control	Combatting mosaic virus and pests in cassava	Resisting viruses and bugs: cassava in sub-Saharan Africa	Cassava transformation in West and southern Africa
Soil fertility	Soil fertility enhancement	Re-greening the Sahel: farmer-led innovation in Burkina Faso and Niger	Sustainable soil fertility management systems
Growth of cotton sector	Rapid growth of cotton production and exports in West Africa	Navigating through reforms: cotton reforms in Burkina Faso	Mali's White Revolution: smallholder cotton, 1960–2006
Growth of smallholder dairying	Smallholder income gains from dairying in Kenya	Dairying in Kenya [included as a Box on p.123]	Smallholder dairying in eastern Africa
Fertiliser market reforms	Policy reforms	Unlocking the market: fertiliser and maize in Kenya	
Control of livestock disease	Control of the devastating rinderpest disease for livestock	Conquering the cattle plague: the global effort to eradicate rinderpest	
Growth of horticultural exports	Expansion of horticulture and flower exports		Are horticultural exports a replicable success story? Evidence from Kenya and Côte d'Ivoire
Banana breeding	Adaptive on-farm breeding of bananas in the Central Highlands		
Growth of rice sector	Increased rice production in Mali		

Sahel' story, with its focus on farmer innovation, food security and adaptation, the success stories are framed by and support the narrative that underpins this strategy: if you allow the market to work and provide access to modern technology, the farmers themselves can deal with the poverty problem.

IFPRI, through the CGIAR, is both funded by the World Bank and closely associated with much of the Bank's thinking about agricultural development in SSA. The CGIAR is also under pressure to demonstrate the value of the 'global public goods' it produces, and to produce these more cost-effectively. The pressure for more coordinated action and greater impact, particularly in SSA, was one factor driving the latest in a series of exercises to reorganise the CGIAR international agricultural research system (CGIAR 2009).

In the space of just a few years, the BMGF has become an important and influential funder of agricultural development in SSA, primarily through the Alliance for a Green Revolution in Africa (AGRA) initiative (Toenniessen et al 2008). The approach taken by BMGF and AGRA, based essentially around technology development and promotion, and greater market engagement by family farmers, fits well with that espoused by the Comprehensive Africa Agriculture Development Programme (CAADP) and the World Bank, and is underpinned by research from the CGIAR. BMGF makes clear its belief that coordinated, strategic investment can pay handsome dividends – or, in their terms, can be transformative – even over the relatively short term. The identification and dissemination of success stories that can demonstrate these transformative effects (to governments, other donors and development actors) is an important part of this strategy.

Finally, the dynamic of success making depends on the fact that individuals and organisations that are actually involved in agricultural research and development on the ground are strongly incentivised to have one of 'their' technologies or projects named and recognised as a success. The validation by recognised international organisations such as IFPRI through the 'rigorous analysis' of 'evidence' would be a public relations coup for most organisations. If handled properly, such an endorsement should increase the influence of the organisation and help secure additional financial resources. The potential benefits of being associated with a success story must explain why so many successes were identified in the early stages of Millions Fed (some 250, of which an unknown number were 'nominated').

Discussion and conclusions

We began this chapter by noting the growing interest in success stories around agriculture in SSA. We then proposed a framework for analysing the dynamic of success making, and used this framework to 'read' success stories from the recent Millions Fed project relating to agronomic research.

If, indeed, the motivation for and dynamic around success making are as we suggest above, it raises important questions for those involved in the funding, management and implementation of agronomic research, and for those who use the results of such research. For example, with pressure to demonstrate impact being felt by development actors at all levels, and with success making being an increasingly important (and understandable) response, we can well imagine that in relation to agronomic research there could be important effects on the following.

- The choice of research areas, problems and questions (e.g. *away from* perennial crops, complex cropping systems and technologies likely to exhibit a high degree of site *specificity*; and *toward* major crops, commercial crops, simple systems and technologies with high spatial transferability).
- The choice of research methods (e.g. *away from* multi-year, multi-site, multi-treatment, multi-disciplinary, appropriately participatory studies; and *toward* short-term, single-site, simplistic studies amenable to 'rigorous' impact evaluation).
- The choice of how results are analysed and communicated (e.g. *away from* a focus on understanding variability, heterogeneity, interactions, contingent outcomes, site and year effects and 'failure'; and *toward* a focus on averages, main effects and inferred impacts with future scaling-up).

This initial exploration of the dynamics of success making also raises important and perhaps uncomfortable questions about the new generation of funders of agricultural research and development in SSA. The framings and narratives employed by some of these new funders and initiatives (including AGRA) foreground notions of rapid, technology-led transformation, effectiveness, payment by results, public–private partnerships and public engagement. But in so doing, are they in effect setting the bar for agronomic research at an unrealistic height? Are they simply adding more fuel to the fire that already has the success making pot at rapid boil; and if so, will this not force research organisations into even more aggressive success making? In this respect, it is important to note that the Millions Fed success stories relating to SSA are built on agricultural research that was conceived and undertaken before the success making imperative became so strong. Would this same long-term research, with its focus on incremental improvements and uncertain 'impact pathways', be funded if it was proposed for the first time today?

We also find ourselves wondering whether the dynamic of success making has the potential to crowd out any possibility of learning from 'unsuccessful' agronomic research (to allow, or even celebrate, 'successful failures'). With a deeply ingrained disciplinary aversion to 'negative results' and a growing premium on success, the temptation to 'big-up' some results while burying research that cannot easily be construed as successful will undoubtedly grow. Acknowledging and finding a way around this trap will be critical if agronomic research is to remain both a useful and a learning-based enterprise.

It was not our purpose to evaluate or contest the success stories put forward by Millions Fed. We do, however, note that around each of the three stories most closely related to agronomic research in SSA – maize breeding, cassava pest control and soil management – there is a considerable body of scholarship. Given that these literatures address agronomic, social and economic concerns, it should not be surprising that they present mixed and often contradictory pictures. In other words, except perhaps for the cassava pest control example, the research literature does not generally point to the kind of unequivocal success alluded to in the success stories, particularly those aimed at non-professional audiences. Analysis (or even simple recognition) of the ambiguities, of the winners and losers associated with agricultural change, goes against the grain in success making. Nevertheless, it must surely remain a central concern of agronomic and rural development research.

Finally, it will be important to analyse the life cycles of the emerging cohort of success stories, and specifically to ask how they will play out on the ground over time. Perhaps even more critical will be careful analyses of if and how these stories are used to influence policy processes around agriculture and rural development, and development assistance more broadly. Do the success stories become 'evidence' in their own right? Do the 'lessons' that are so carefully woven into these stories become central to ongoing contestation and negotiation around agricultural research policy and practice; and how do they ultimately affect the narratives that drive the politics of these processes?

Notes

1. Parts of this chapter draw on Irving, R. (2010) 'Narrating success: an analysis of the process and politics of success stories in African agricultural development', MA dissertation, Institute of Development Studies, University of Sussex, Brighton.
2. A Green Revolution for Africa: Fulfilling the Borlaug Dream, Keynote speech delivered by Dr Akinwumi A. Adesina, Vice President, Alliance for a Green Revolution in Africa (AGRA), Feeding the Future Borlaug Symposium 2010, 13–14 July, Addis Ababa, Ethiopia (www.agra-alliance.org/content/news/detail/1172)
3. For a variant – termed 'progress stories' – see www.developmentprogress.org. The interest in development success stories is not limited to African agriculture, but can also be seen in relation to health (Levine 2004, 2007).
4. Operationally this becomes less elegant, with potential successes being judged against criteria

relating to importance, scale, time and duration, proven impact and sustainability (Spielman and Pandya-Lorch 2009b: Annex B. Methodology).

5. In this regard the Failure Report published annually by the NGO Engineers Without Borders Canada is an interesting initiative: www.ewb.ca/en/whoweare/accountable/ failure.html.
6. WARDA (now the Africa Rice Centre or AfricaRice) is the CGIAR-supported research institute where work on the NERICA varieties was initiated.
7. Monty Jones, who was instrumental in the development of NERICA rice, was awarded the World Food Prize in 2004; WARDA received the King Baudouin Award in 2000 for the NERICA work.
8. For example, DFID (currently www.dfid.gov.uk/Media-Room/Press/?tab=2; past http://webarchive.nationalarchives.gov.uk/+/www.dfid.gov.uk/aboutdfid/dfidsuccesses.asp); USAID (www.usaid.gov/stories/archiveafr.html); BMGF (www.gatesfoundation.org/agriculturaldevelopment/Pages/default.aspx); ICRISAT (www.icrisat.org/icrisat-impacts. htm); Africa Bio (www.africabio.com/pages/farmers-biotech-success.php); AGRA (www.agra-alliance.org/section/people/stories); FARMAfrica (www.farmafrica.org.uk/cms.php? page=3; www.youtube.com/profile?user=FarmAfrica#p/u/12/zUZYTCAOQHk); Pioneer (www.pioneer.com/web/site/portal/ menuitem.07de136cde40c7ff21332133d10093a0/)
9. The chapter on maize breeding, for example, contains a full-page box labelled 'The techniques and technologies of breeding better maize' that distinguishes between single- cross hybrids, double-cross hybrids, three-way hybrids, top-cross hybrids and varietal hybrids.
10. IFPRI video: Millions Fed: Proven Successes in Agricultural Development (www.youtube.com/watch?v=xHZqtIWi-l8); on 23 August 2010 YouTube reported that since 7 November 2009, the Millions Fed video had been viewed 2953 times.
11. Two images (pp. 5 and 14) were excluded from this count as the gender of the image subject was not identifiable.
12. One image (p. 13) was excluded from this count as the gender of the image subject was not identifiable.
13. It is interesting to note that none of the three images in the chapter entitled 'Re-greening the Sahel: farmer-led innovation in Burkina Faso and Niger' depicts either people or action (two depict zai planting pits and one is a landscape shot)

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CHAPTER 2

What is Climate 'Smartness'?

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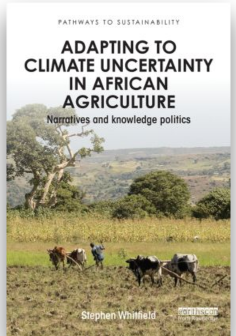

The following is excerpted from *Adapting to Climate Uncertainty in African Agriculture: Narratives and knowledge politics* by Stephen Whitfield.

Learn more:

A review of case studies of 'climate smart agriculture'

Incomplete knowledge and narratives of climate smart agriculture

Since its rise to popular discourse in the early 2010s, a 'climate smart' label has been applied to a range of agricultural innovations and development projects across diverse African contexts, each, as in the case of conservation agriculture and water-efficient maize, associated with claims about simultaneously increasing productivity, building resilience to climate change, and reducing greenhouse gas emissions. The cases discussed in the previous chapters reveal a conflict between the widely held goal of achieving these triple wins at regional and continental scales through innovation, and recognition of the need for these innovations to be shaped by contexts and capacities that are heterogeneous, even at local resolutions. In the following meta-analysis of CSA case studies, which draws broadly on recent peer-reviewed literature, this is shown to be a widely applicable argument, and one that is in some cases being counteracted by a movement away from technology-centred agricultural development.

Where the advocacy of a single, narrowly defined technology is at the centre of a 'climate smart' strategy, incomplete knowledge about diverse and complex local level farm systems can quickly become lost within convincing and political narratives, and the evidence bases that are developed to support them. Impressive performances within controlled field trials are often cited as key evidence bases underpinning, sometimes elaborate, narratives of societal impact associated with agricultural technologies, and these justify ambitious adoption targets and investments in 'scaling up'. That such performance is rarely realised on farms, because the trial station simulations inevitably fail to fully reflect a multiplicity of realities, gives cause to question the legitimacy of these broader narratives. This chapter describes the contested nature of field trial evidence and the extrapolation of this incomplete knowledge into 'evidence-based' upscaling arguments in a number of 'climate smart' technologies that have been developed and advocated across sub-Saharan Africa.

Whilst rigidly defined and tested technologies may be associated with upscaling initiatives, a CSA label is increasingly attached to a growing number of more flexible, or 'platform', technologies (of which conservation agriculture can, in some cases, be considered) for which there is a necessary emphasis on 'down-scaling'; the adaptation of practice to suit particular local systems, often through farmer-led experimentation and innovation. Platform technologies can usually be considered as a set of agronomic principles that might manifest in a variety of on-farm practices, cropping strategies and resource allocations. Unlike with single, narrowly defined technologies, underpinning such approaches is recognition of the uncertainty that results from diverse and dynamic agricultural systems, and the need to open up definitions of CSA to respond to this uncertainty. In this chapter it is argued that the modification and adaptation of flexible agricultural practices at the farm level, such that their appropriateness and performance is optimised within a continually reflexive and social learning-based process, is an important component of climate smartness. Such socio-technological interactions are inherently incompatible with limited trial site-derived evidence bases and the setting of broad adoption targets. However, projects that promote approaches that are, at a rhetorical level, flexible and adaptable, have often fallen foul of the financial and political lure of overstated narratives and 'technology-for-all'-type statements. Whilst the importance of flexible technologies and local level adaptations is broadly recognised, this sentiment is not easily reconciled with the scaling-up agendas and setting of ambitious adoption targets that are an indirect consequence of competitive funding environments, private sector partnerships, and the scale and urgency of the challenges of food insecurity and vulnerability to environmental change.

The imperatives of technology development are such that there is a danger that within a technology-focused CSA paradigm, assessments and evidence bases are comprised of technical and controlled experiments rather than on-farm participatory evaluations; there is an over-hyping of success claims and preoccupation with adoption rates and targets; and the role of agricultural extension becomes that of issue advocates and salesmen. Problematically, this can act to shift focus away from the contextualised challenges of building climate smart farming systems, and even compromise or close down alternative, locally appropriate strategies.

By contrast, a concern for socio-technical systems, as opposed to a rigid technology-centred mindset, in some cases has manifest in a new discourse around CSA, which, rather than being preoccupied with outcomes and impact, focuses more broadly on the processes by which agricultural systems are designed; with particular emphasis on social learning and reflexivity.The facilitation of participatory research, improvement of information and market access, building of knowledge-sharing platforms, and empowerment of women, are in some quarters, beginning to be considered as fundamentals of climate smartness. Such endeavours essentially act to delink notions of climate smartness from particular technologies or practices and open up the concept to negotiation, learning and multiple rationalities. Several examples of such approaches to building climate smartness in sub-Saharan Africa are described here and, whilst advocated, the potential contradictions and challenges of these process-oriented approaches are also discussed.

Technology adoption as climate smartness?

The previous two chapters present agricultural research and development as a search for technologies of broad relevance and no-compromise benefits. Perhaps surprisingly, a quick reading of literature on African agricultural success stories, for example the IFPRI Millions Fed project (Spielman and Pandya-Lorch 2009) or the UK government's Food and Farming Futures Foresight Review (Pretty 2011), suggests that such silver bullets are not as elusive as one might be led to believe. Agroforestry, micro-irrigation, improved crop varieties, pest management technologies and soil fertility enhancements have been at the centre of countless agricultural development projects, by a range of public, private, governmental and non-governmental organisations across Africa, many of which are associated with similar multiple-wins claims. Table 6.1 provides background information on three projects, associated with different technologies, regions and institutions, but similar multiple-wins narratives.

- New Rice for Africa (NERICA) refers to rice varieties selected from amongst a progeny of inter-specific crosses of Asian (Oryza sativa) and African (Oryza glaberrima) rice. Inter-specific crossing was initiated by West Africa Rice Development Association (WARDA, now the Africa Rice Centre) in an effort to combine the productive potential of the Asian varieties with traits from African rice including weed competitiveness and tolerance to biotic and abiotic stresses. Inter-specific crossing was initiated at WARDA in the early 1990s with a particular focus on the rainfed production ecology (Harsch 2004). Working with scientists in West African national research systems and farmers (through the Participatory Variety Selection (PVS) methodology), WARDA named the first seven NERICA in 2000. Work on 'lowland' NERICA, for use in the inland valley and irrigated production ecologies, began in 2000. By 2006 some 78 NERICA varieties had been named (Diagne et al. 2010). From very early in the development phase the NERICA germplasm was promoted by WARDA and others through a series of oft-repeated and in some cases quite spectacular claims about their technical characteristics (i.e. yield potential, weed competitiveness, stress tolerance and grain protein levels) and about the rate and extent of their dissemination and impacts. These have been brought together in a powerful narrative that has been and continues to be used to drive rice development policy in Africa. Specifically, NERICA was the basis of the Africa Rice Initiative (ARI) and figures prominently in the work of the Coalition for African Rice Development (CARD).The early experience with the new rice varieties in Guinea, Burkina Faso, Côte d'Ivoire,The Gambia, Ghana, Mali and Nigeria became central to the broader NERICA narrative.
- Push–pull approaches to pest management in cropping systems have been

developed and trialled since the 1970s and based on a dual mechanism of in-field planting of pest repellent crops in-field and bordering fields with an attractive trap crop. The International Centre of Insect Physiology and Ecology (ICIPE), a CGIAR institution with offices in Nairobi, has, in collaboration with the Rothamstead research centre in the UK and the Kenya Agricultural Research Institute developed a particular push–pull system aimed at tackling stem borer infestations in maize.The system, which comprises the intercropping of desmodium varieties (a fodder legume) with maize and planting a border of Napier grass, makes claim to having additional benefits in relation to the suppression of *Striga* weed and the fixing of soil nitrogen (Khan et al. 2011). As well as repelling stem borer moths, desmodium helps to suppress *Striga* through its dense ground cover and allelochemical properties. Napier grass, which represents a preferred egg-laying plant, compared with maize, for stem borer moths, also produces a sap that suffocates stem borer larvae (Khan et al. 2011). It is a system that is particularly suited to mixed livestock-crop systems because of the fodder nature of the push–pull varieties (Khan, Amudavi et al. 2008, Khan, Midega et al. 2008) and it is being promoted through an ICIPE extension and farmer field school programme in western and central Kenya, Uganda and northern Tanzania (Amudavi et al. 2009).The stated goal of the ICIPE programme is 'to *end hunger and poverty for 10 million people by extending Push-Pull technology to 1 million households in sub-Saharan Africa by 2020*' (Push-Pull.net, no date), and estimates from 2011 suggested that it was being practised by over 30,000 farmers in its initial target areas (Khan et al. 2011), and in 2014 the ICIPE website claimed that this figure was 89,000.[1]

- The system of rice intensification (SRI) was conceived and developed through on-farm research by a missionary working with farmers in Madagascar in the 1980s and is thought to represent an optimisation of rice productivity through careful observation and experimentation of the plant phenology (Stoop et al. 2002, Uphoff 2003). It was observed, for example, that rice does not necessarily thrive under flooded conditions, that growth potential is compromised if transplanting takes place more than 15 days after emergence, and that plant spacing affects tailoring and root growth (Stoop et al. 2002, Sheehy et al. 2004). In response to these observations a number of practices for optimal production have been outlined, and these are generally categorised into six principles: '(1) raising seedlings in a carefully managed, garden-like nursery; (2) early transplanting of eight to 15 days old seedlings; (3) single, widely spaced transplants; (4) early and regular weeding; (5) care- fully controlled water management; and (6) application of compost to the extent possible' (Stoop et al. 2002: 252). Evidence from trial stations in Madagascar suggests that the system may produce yields of up to 20 tonnes per hectare (compared with a national average yield which is approximately 3 tonnes) and has been the basis of claims about SRI leading a new green revolution (Uphoff 2003). Although much research and investment in SRI adoption and upscaling has focused on India, China and southern Asia, new USAID and Africare projects have sought to develop and promote the technology in Mali and elsewhere in western Africa (Styger et al. 2011).

To demonstrate the broad applicability of some of the arguments made in the previous chapters, a brief review of the knowledge gaps that underpin these varied innovations is presented below. Emphasis is placed on the uncertainties of translating field level evidence into resource-constrained, innovative and nuanced farming practices, which often do not reflect either the 'conventional' or technological systems constructed in controlled field trials, but changeable hybrids or modifications of these. Favourable comparisons of the yield of technologies or specific practices versus a 'conventional' control plot are regularly referred to as convincing justifications of narratives of agricultural and societal change. At the same time, however, the legitimacy of such assumptions and the limitations of trial site evidence are broadly acknowledged, even by proponents of the technology. Stoop et al. (2002) and Styger et al. (2011), for example, whilst heralding the impressive performance of SRI under controlled conditions, similarly appreciate that there is a need for further investigation of its phenological mechanisms and their relationship to different agro-ecological conditions (e.g. relationship between root development, soil properties and nutrient uptake), and Kijima et al. (2008), a NERICA proponent, recognises the need for further investigation into its performance and profitability under variable rainfall conditions. It is not uncommon to find 'evidence-based' advocacy and calls for the strengthening of, or gap-filling within, these evidence bases side-by-side, particularly within the language and outputs of institutions, such as those of the CGIAR, that simultaneously play the role of researcher and issue advocate.

From field trials to farming

There are, of course, limitations to the accuracy and completeness with which trial sites can replicate heterogeneous real-world systems. Complex farm systems vary in their agro-ecological properties and resource constraints and farmers may adopt, experiment with, and modify practices in multiple ways that negate the real-world relevance of those particular systems that are simulated and tested in crop trials. The affordability of improved varieties, planting machinery, fertiliser, pesticides and herbicides, or additional labour, as required by different agricultural technologies may limit farmers' capacity to adopt and practise them in ways that are optimal, and represented in trial

TABLE 6.1 Programmes and narratives associated with three agricultural technologies that have been promoted as 'climate smart'

Innovation	*E.g programme*	*Institutions*	*Narrative*
Improved varieties	New Rice for Africa Project (West and Central Africa)	WARDA	'NERICA . . . can revolutionize rice farming in Sub-Saharan Africa: rice that will produce a crop with minimal inputs in Africa's stress-afflicted ecologies, and that will respond bountifully as soon as farmers have the means to apply additional inputs. By 2000, over 20,000 farmers were growing NERICA varieties in Guinea alone, and the varieties look set to spark a rice-based agricultural revolution in West and Central Africa' (WARDA 2001: 1).
Integrated pest management	Push–Pull Maize (Kenya, Tanzania, Uganda, Ethiopia)	ICIPE	'Growth in agricultural productivity is essential to reduce hunger and poverty and ensure food security. Agricultural growth can be achieved by reducing incidence of the major constraints to productivity such as pests, weeds and degraded soils . . . Push-Pull technology has been developed for integrated management of stem borers, striga weed and soil fertility' (www.push-pull.net/). 'It is . . . envisaged that within the next five years approximately 50,000ha will be under push–pull technology, thereby lifting about 100,000 households out of food insecurity' (Khan *et al.* 2011: 165).
System of rice intensification	IICEM (Initiatives Integrées pour la Croissance Economique au Mali) (Mali)	Africare, USAID	'SRI increases the productivity of resources used in rice cultivation, reducing requirements for water, seed, synthetic fertilizers, pesticides, herbicides and often labour – especially tasks performed by women. SRI represents an unprecedented opportunity for developing economies to enable these households to be more productive, secure, and self-reliant, while buffering and even reversing the trends that contribute to climate change. This is a win-win-win situation for rural households, countries and the planet' (Africare Oxfam America WWF–ICRISAT Project 2010: 2–3).

sites (Styger et al. 2011, Jerneck and Olsson 2013). In the case of push–pull technologies, interpretations of a universally impressive set of published trial sites results should be tempered by a consideration of the constraints that limit its optimal practice within smallholder farming systems. Khan, Midega et al. (2008) acknowledge that access to seed may be a limiting factor, and others have pointed out that land limitations, particularly for crop-only smallholder systems, may restrict the broader relevance of crop trial tested designs of integrated pest management (Lançon et al. 2007). Similarly, levels of mulch application and herbicide usage often fall below the minimum recommendations of CA extension in Malawi and Zambia as a result of the high market and opportunity costs (Nyanga 2012, Andersson and D'Souza 2014, Whitfield et al. 2015), and Glover (2011) describes a number of observations of SRI practice (in Nepal) in which labour shortages have resulted in compromises in spacing distance accuracy, weed management and soil aeration.

Many technologies are knowledge intensive and rely on networks of training and knowledge dissemination through demonstration farmers. In the case of the ICIPE programme, push–pull technology is being advanced through lead farmers and farmer field schools and relies on the exchange of knowledge and training through social networks (Amudavi et al. 2009). This is a model that is commonly followed in innovation dissemination, but can be prone to miscommunications or limited capacity for continual training and support. As such, information and technical capacity can represent a significant determinant of how agricultural technologies manifest in real-world systems. I visited a lead-farmer based CA programme in Golomoti in Malawi, where such challenges were evident in the fields of one of the programme's 'follower' farmers. Surprised by the sparseness of a cowpea field that was in rotation with maize, I had asked about the recommendations that the farmers, an elderly couple, had received about growing cowpeas.They explained that in the absence of advice during the busy planting period, they had simply planted in the holes left by the maize stalks of the previous season, with the result that the plant spacing was several inches greater than necessary, and the productivity of the field, therefore, compromised. A lead farmer explained that, whilst they received a good level of training and continued support through the programme, they had limited capacity to extend this across the large networks of farmers (one lead farmer may have up to 21 followers) that depended on them for technical advice.

As well as constraints, the practice of technologies and techniques are regularly adapted within farm systems as a result of experimentations, social learning and the development of hybrid strategies. Glover (2011) outlines three reasons why practised farming might look quite different to that which is anticipated and trialled within agricultural development projects. He recognises: (1) the dynamic and differentiated nature of farming systems in which farmers respond to seasonal and geographic variations and variability by altering practices accordingly across space and time; (2) that farmers make judgements on the basis of multiple rationalities, which revolve not just around the optimisation of productivity, but may prioritise communal benefits; secure food supplies; risk spreading; or other outcomes that rationalise alternative strategies; and (3) that, rather than new practices simply replacing old, multiple technologies and practices may co-exist, either side-by-side or in hybrid forms. Innovative variants on technologies, e.g. duplicated transplants of rice in SRI in response to low levels of rainfall (Glover 2011) and alternative push plants in response to different concerns about weeds and pests in push–pull management (Cook et al. 2006, Khan, Amudavi et al. 2008, Khan et al. 2011), are observed examples of technology adaptations resulting from farm system-level innovation.

Contested evidence bases

Despite a broad recognition of the limitations of trial site evidence in reflecting real-world practice, and the associated assumptions inherent in the methodological design of controlled trial experiments, critiques of trial site design and the robustness of trial site data and its analysis are often highly controversial. In relation to NERICA trials, Orr et al. (2008) review publicly available data from NERICA trials (Jones et al. 1997,WARDA 1997, Rodenburg et al. 2006) and argue that it is highly inconclusive in regards to yield performance and weed competitiveness, in comparison to existing *sativas* and *glaberinna* varieties. Sheehy et al. (2004) are particularly critical of yield claims around SRI (such as those presented at the 2002 International Conference on Assessment of SRI: Fernandes and Uphoff 2002, Rafaralahy 2002) and in their own trials conducted in three locations in China find 'no consistent difference in yield between SRI and conventional practice' (p. 4), leading them to claim that 'the extraordinarily high yields (ca. 20 t ha-1) obtained using the SRI in Madagascar are probably the consequence of some form of measurement error' (p. 7).They criticise the lack of disclosure of information about the experimental design, choice of cultivars, planting and harvesting dates, soil types, and sources of statistical error in the presentation of trial station results from Madagascar:

> The advocates of the system of rice intensification (SRI) have claimed both the world record for rice yield and the highest yields (by a substantial mar- gin!) for any grain crop (Rafaralahy, 2002). This is curious because none of the usual information expected in support of these 'fantastic yields' was presented to support the claim. Absent were data concerning cultivar, experimental design, statistical errors, dates of planting and harvesting, soil types, fertilizer inputs, weed control, disease control, insect control, water management and the weather.

(*Sheehy* et al. *2005: 355*)[2]

In response, Stoop and Kassam (2005) have leveraged similar criticism at the design of trials conducted by Sheehy et al. (2004) in China:

> Sheehy et al.'s field research had serious methodological flaws.The field experimentation conducted in China for a single season and exclusively on experiment stations was of very limited scope and employed water and (mineral) fertilizer regimes inappropriate for SRI.The soil under SRI was kept saturated through daily irrigation during the vegetative stage, thereby creating anaerobic soil conditions. Mineral fertilizer applications were excessively high (180–240 kg N/ ha) and along with an incidental application of 1500 kg/ha rape seed cake bypassed the real nature of the problem, which is medium to long term and involves a need to redress the soil's organic and biological properties.

(*Stoop and Kassam 2005: 359*)[3]

These disputed evidence bases are indicative of the ambiguities of trial site design and suggestive of the potential for such design to be oriented towards results that support preconceived arguments. The presentation of field trial data from organisations involved in the development of the innovations described above, unsurprisingly indicates good performance in terms of increased productivity. ICIPE have published the findings of push–pull trial site and on-farm experiments in a number of high profile academic journals in all cases showing a significantly favourable yield when compared with a mono-cropped control run (Khan et al. 2011). Publications from WARDA (in relation to NERICA) (Somado et al. 2008) present a similarly convincing evidence base. Many critics have argued that the narratives advanced in promotional projects and programmes are the product of a mutually reinforcing science-policy interaction, in which 'positive evidence is given more weight than negative and data that could contradict prevailing enthusiasms are given limited attention or not collected at all' (Coe et al. 2014: 74) and such tendencies may reflect institutional norms and protocols rather than conscious misrepresentations of data, particularly once research institutions become established as technology advocates, as in the case of ICIPE and push–pull technology.Trial site evidence is a valuable indicator of technology performance and an important component of technology development, particularly as trials expand to cover multiple agro-ecological conditions, or test multiple combinations and adaptations of practice (Styger et al. 2011), but it is necessary to acknowledge that, in some cases, they represent areas of methodological ambiguity and contested science.

As well as extrapolative assumptions from incomplete trial site evidence, it is also possible to identify success claims that are constructed in the other direction, on the basis of identifying and attributing positive national-level statistics (e.g. production). These initial evidence bases are often similarly incomplete, and attributing them to specific technologies and practices is similarly reliant on questionable assumptions. NERICA germplasm has been promoted by WARDA and others through a series of oft-repeated and in some cases quite spectacular claims about their technical characteristics (i.e. yield potential, weed competitiveness, stress tolerance and grain protein levels) and about the rate and extent of their dissemination and impacts (Whitfield 2012). There are a number of examples of NERICA success claims which utilise national agricultural statistics as a supportive evidence base, without recognition of the incompleteness and unreliability of these statistics or the problems of attributing change (Whitfield 2012):

> In Burkina Faso . . . domestic rice production increased by an astonishing 241% in 2008 compared to 2007, [this] was attributed partly to NERICA varietal adoption by the FAO Rice Monitor.
>
> (*AfricaRice 2007: 1*)

FAO data shows that rice production in Burkina Faso reached and exceeded 200,000 tonnes per annum in 2008/2009. More specifically, the data show a period of significant growth in rice production in the early 1990s, followed by a decade of stagnation; 2007 was a poor year, but production then increased dramatically in 2008. Total production in 2008 and 2009 was twice the average production between 1994 and 2006. Over the course of this time series, national agricultural censuses were conducted in 1994/1995 and 2007/2008 and, given the limited nature of monitoring in the intervening years it is not surprising that the points of significant change in rice production coincide with the agricultural censuses. Whilst the large rise in 2008 production may be real, it is also likely that the error margins on the extrapolated estimates from the previous years' sample surveys were much greater than those associated with the 2007/2008 census data. A lack of reliability in the data preceding the production growth significantly compromises this legitimacy. It is not possible, for example, to determine the extent to which such an increase in production should be attributed to an improvement in data accuracy as compared to genuine production growth.

Whilst there is undeniable evidence that adoption rates of NERICA have been high in certain locations (Somado et al. 2008, Diagne et al. 2009); that there are several properties of NERICA varieties that are beneficial in a number of agro-ecological settings (such as early maturing, short straw and tolerance to water stress) (Somado et al. 2008,Tollens et al. 2008, Rodenburg et al. 2009, Oikeh et al. 2010); and that some farmers have realised productivity gains as a result of NERICA adoption (Agboh-Noameshie et al. 2007, Diagne et al. 2010, Dibba et al. 2012), yield increases and other benefits are variable and not universally realised (Kijima et al. 2008,Tollens et al. 2008, Kudi 2010). Kijima et al. (2008) record high rates of disadoption of NERICA varieties in their panel survey of 347 households in Uganda, citing the 'low profitability of NERICA relative to alternative crops in variable rainfall areas' as a major cause; indicative of the limitations of extrapolating from trial site evidence, particularly across agro-ecological conditions. A paucity of observations of socio-technical systems that seek to understand the ways in which technologies and techniques are practised across complex, constrained and dynamic real-world systems represents a significant source of incomplete knowledge in the gap between field trial data and national agricultural statistics.

Where the incomplete evidence derived from crop trials or national agricultural statistics becomes the basis of narratives about the societal impact of a technology it is likely to result in unrealistic expectations and unrealised results. In their Program and Management Review of the Africa Rice Centre report, Tollens et al. (2008: 82) warn that:

> For institutions that rely only on donor funds to survive, the temptation is strong to oversell potential products and breakthroughs to donors . . . The Panel thinks that WARDA too needs to be cautious with the NERICA story and the way it is sometimes reported, probably by excess enthusiasm . . . The temptation to present NERICAs as a solution to all African rice problems risks undermining truly good scientific work and real impact.

Extrapolations from trial site performances into sweeping narratives of societal impact inevitably overlook aspects of farm system diversity, the dynamic nature of farm management, the multiplicity of rationalities underpinning decision-making, and the varied forms that technology adoption takes. Problematically, these underlying assumptions are all too often hidden within success story narratives that are attractive to donors and policy-makers. As in the case of CA, these optimistic expectations form the basis of calls to scale up technologies and set ambitious adoption targets, whereas a critical reflection on these underlying assumptions, and their appropriateness across diverse farming systems, might rather point to the importance of scaling down.

Platform technologies: from scaling up to scaling down

> A process of translation is always necessary to convert theoretical models or norms into farming practices. Smallholder farming practices, being intrinsically constrained and contingent, rarely conform precisely to abstract norms.
>
> (*Glover 2011: 217*)

In Chapter 3, the diversity of farming systems, strategies and rationalities was introduced and is an important driver of the 'translation' of technologies into on-farm practices, something which is contradictory of adoption targets and measurements, but also creates challenges for the conversion of field trial evidence into assumptions about societal impact. The development of loosely defined technologies, based on general agronomic principles rather than strictly defined practices, is a response to some of the problems associated with the latter. Although a lack of strict definition of agricultural technologies can be a source of criticism – for example in arguments about the 'incorrectness' of trial site design – flexibility in practice and adoption has been heralded as a positive attribute of 'platform technologies'. Such technologies are based on adaptable principles rather than prescriptive management strategies and may have multiple and diverse manifestations.Two practices that have already been discussed, CA and SRI, are increasingly thought of as such, and in the following discussion two others are also referred to: integrated soil fertility management (ISFM) and agroforestry, the principles of each is described in Table 6.2.

TABLE 6.2 Outline of the main principles of four 'platform' technologies for agricultural development

Platform technology	*Principles/practice*
Integrated soil fertility management	• Mineral fertiliser, pH-balancing, and organic matter inputs relevant to the improvement of soil quality • Above-ground practices (improved germplasm, agroforestry, crop rotations, intercropping) relevant to the improvement of soil quality
Agroforestry	• Use of 'working' trees (for fertilisation, food, fodder, fuelwood, medicine, resin products, etc.) within agricultural systems
Conservation agriculture	• Minimal tillage • Permanent organic soil coverage • Crop rotations/intercropping
System of rice intensification	• Raising seedlings in a nursery • Early transplanting of seedlings • Widely spaced planting of individual seedlings • Good weed management • Controlled water management (not usually flood irrigation) • Management of soil nutrients

Integrated Soil Fertility Management (ISFM) is a term that has come to represent a variety of practices, usually involving the application of a combination of mineral fertiliser and organic matter, that aim at improving the agronomic use efficiency (AE) of those inputs and the crop productivity of soils (Vanlauwe et al. 2010). Above-ground practices, such as agroforestry or crop rotations, that act to improve soil quality, may also be considered an important component of ISFM in some contexts (Sanginga and

Woomer 2009). ISFM has been developed and advocated across sub-Saharan Africa through a variety of projects and organisations, including the Soil Health Programme of AGRA and by the Tropical Soil Biology and Fertility Research Area of the International Centre for Tropical Agriculture (TSBF-CIAT) and the International Institute of Tropical Agriculture (IITA). Importantly, increasing AE and soil productivity requires practices and inputs that respond to existing and local soil properties, as well as availability and access to inputs (Vanlauwe and Giller 2006).Vanlauwe et al. (2010) argue that responding to the conditions and constraints of farming systems is a key component of ISFM:

> At the regional scale, overall agro-ecological and soil conditions have led to diverse population and livestock densities across SSA and to a wide range of farming systems. Each of these systems has different crops, cropping patterns, soil-management considerations, and access to inputs and commodity markets. At the national level, small-holder agriculture is strongly influenced by governance, policy, infrastructure, and security levels.Within farming communities, a wide diversity of farmer wealth classes, inequality, and production activities may be distinguished. At the individual farm level, it is important to consider the variability between the soil fertility status of individual fields, which may be as large as differences between different agro-ecological zones. Any definition of ISFM must consider these attributes.
>
> (*Vanlauwe* et al. *2010: 18*)

In different contexts it may be necessary to build nitrogen, potassium or phosphorus content, neutralise acidic soils, increase levels of soil organic carbon and organic matter, or a combination of these, and the required access to mineral inputs (Place et al. 2003), capacities to produce compost (Omiti et al. 1999), and the availability of seeds for rotation or residue crops differ; this has resulted in varied manifestations of ISFM by African smallholders (Place et al. 2002, Place et al. 2003). ISFM studies have identified the use of: improved fallows and biomass transfer as a result of agroforestry development programmes (extension services and input support) in Western Kenya (Place et al. 2004, Place et al. 2005); legume-maize rotations with added phosphorus (during legume phase) and minimal nitrogen fertiliser (during cereal phase) in dry savannah regions of Nigeria (Sanginga et al. 2003,Vanlauwe et al. 2010); and precision micro-dose fertiliser applications in sorghum and millet systems in areas of Burkina Faso, Mali and Niger (Bationo et al. 1998, Tabo et al. 2007,Vanlauwe et al. 2010), as just some examples of adapted manifestations of ISFM.

Agroforestry – broadly defined as the use of 'working' trees (for fertilisation, dryland regeneration, food, fodder, fuelwood, medicine, resin products, etc.) within agricultural systems – is promoted in a variety of forms; multiple tree species (Faidherbia, Cordyla

Acacia Leucena, Gliricidia,Tephrosia, etc.) in a range of agroforestry systems (see Figure 6.1). ICRAF and the University of Copenhagen have developed the 'Useful Tree Species for Africa' database that details hundreds of location specific systems across the continent,[4] which reflect not only agro-ecological variation, but diverse socio-technical systems. Sahelian parklands represent communal and participatory systems of multi-use forest products, cocoa systems in humid west Africa, east African rotational woodlots, alley/inter-cropped cereal systems, improved fallows, and the use of fodder trees in mixed-crop-livestock systems, all represent diverse examples of agroforestry, which, in many cases, are advocated as part of other agricultural platform technologies, such as CA or SRI (e.g. Garrity et al. 2010), and have been given impetus by schemes that aim to incentivise carbon storage and management (e.g. REDD+ schemes).

The core principles of CA – which are widely accepted as being (1) minimal tillage; (2) permanent organic soil cover; and (3) crop rotations or intercropping – have multiple manifestations, which result from a combination of farming systems constraints and innovation histories, as described in the previous chapter. In Zambia, for example, where CA advocacy has focussed on low rainfall areas, aver- age access to draught power is relatively high and dry season planting has been advocated within a long history of reduced tillage advocacy, the use of ox-drawn ripping technologies (e.g. the Magoye ripper) is a much more common component of CA than it is in Malawi (Haggblade and Tembo 2003, Andersson and D'Souza 2014). The high density of rural areas and the prevalence of particularly small (subsistence-based) land holdings has been given as a reason for a lack of emphasis on crop rotations within CA in Malawi, where intercropping and the addition of agroforestry have been differently advocated as part of CA packages (Andersson and D'Souza 2014). In Zimbabwe, where many farmers were introduced to CA through small-scale famine relief programmes, offering small input packages, precision fertiliser inputs became a necessary part of CA practice (Marongwe et al. 2011).

Whilst SRI is broadly defined as the practices outlined earlier, these can manifest in multiple practices in the varied contexts in which it has been developed and advocated. Berkhout and Glover (2011) present the findings of a systematic review of literature on SRI in Madagascar, India and China, which they describe as representing diverse agro-ecological and socio-institutional farming contexts, and find that across this literature, whilst wetting and drying irrigation and mechanical weed suppression are consistently noted as SRI practice, other components of soil management (e.g. relating to fertiliser application) are much less consistent. They also note variations in the prescribed age for transplanted seedlings varying both within and between these contexts, and cross-context differences in prescribed numbers of seedlings per hill and plant spacing distances. Variations of SRI in Madagascar include the Mitsitsy Ambioka sy Fomba Fiasa (MAFF) system, a low investment variation aimed at resource-poor households, which allows for later seedling trans- plantation (than typical SRI) to avoid the risk of loss from handling fragile seedlings, and prescriptions about planting density and placement that are less rigid than in other SRI systems (Berkhout and Glover 2011).

Adoption as adaptation

Whilst adoption rates of technologies are often cited as evidence of impact, or even success, 'adoption' is often weakly defined in relation to such statistics, with details about the area, and length of time over which specific practices are conducted, often not specified within impact assessment studies (Loevinsohn et al. 2013). In the case of platform technologies, because of their varied manifestations, identifying these specifics is particularly problematic, but the incentive to conform to an established convention of 'adoption rates as impact' has, in some cases, resulted in a compromise of quasi-prescriptive platform technologies.

Projects and strategies differ in the extent to which they impose predefined ideas about agricultural practice or open up these outcomes to negotiation and co-design. In some platform technologies, a distinction is made between component practices that are core, and to which there is an obligation in order to be considered an adopter, and those which are peripheral Technologies, such as in CA and SRI, are associated with a set of core (or non-negotiable) practices – usually minimal tillage in the case of CA and water management, early transplanting, and weed suppression in the case of SRI – and other optional or malleable component practices – such as crop rotations in CA and fertiliser regimes, spacing distances, number of days (or level of maturity) to transplanting, seedlings per hill, in SRI, which can vary and need not be practised in any specified manner as a condition of adoption. These core practices might be those for which positive impact has been best supported by evidence, or are considered prerequisites for peripheral practices to be effective. Technologies, such as ISFM, may be associated with hierarchical or ordered practices; in which those practices that are prioritised depend on prerequisite practice or conditions. Vanlauwe et al. (2010) explain that the degree of degradation and responsiveness to fertiliser of soils deter- mines the necessary order and prioritisation of practices in ISFM. In responsive soils, fertiliser application and the use of improved germplasm represent first-order components of ISFM, in other cases low levels of soil organic matter (SOM) may be a constraint on the AE of soils, requiring the prioritisation of organic inputs.

However, the appropriateness of these compromises in the flexibility of platform technologies in order to conform to the ideals of adoption measurement and impact metrics is questionable. Such technologies should arguably be, and in some cases are, a part of a movement towards rethinking the meaning of what it is to adopt technology. Discourse around ISFM, and increasingly CA and SRI, emphasises local adaptations of the technology as a central and requisite component of adoption (McCarthy et al. 2011, FAO 2013); the altering of technologies to best suit circumstances as representing a fundamental part of what it is to 'adopt', as suggested in this CIMMYT paper on CA:

> Local investments in adaptive research are typically needed to tailor conservation agriculture principles to local conditions.This process of 'tailoring' is most efficient when an 'innovation system' emerges and begins to acquire a self-sustaining dynamic.
>
> (*Harrington and Erenstein 2005: 32–33*)

A shift towards thinking about farm-level adaptations, as opposed to the adoption of rigidly defined technologies, accommodates some degree of integration of the contextualised local knowledge of farmers within the process of innovation.Whilst the scaling up of agricultural technologies is often underpinned by a denial of the uncertain nature of compatibilities between diverse farm systems and agricultural technologies, recognition of this uncertainty is central to the rationality of platform technologies. This requires attention to be paid to the farm-level interactions between constraints, livelihoods, knowledge systems and technology usage; the 'scaling down' of agricultural technologies.

Jansen and Vellema (2011), following Richards (1989), describe a multi-disciplinary approach to studying experiences of technology-in-use. They see agriculture as a performance of tasks that is the product of multiple knowledges and rationalities and institutionalised rules and routines, the study of which requires an ethnographic, multi-question and multi-sited approach that can capture an understanding of the social and institutional components of agricultural systems as well as agronomic and technical ones. Glover advocates a technographic approach to the analysis of SRI:

> In agriculture, the technographer's focus falls on farmers' practice, which she expects to be complex, dynamic, diverse and strongly shaped by farmers' agency as well as local and temporal contexts. By placing empirical observation of farmers' actual behaviour and activity at the centre of analysis, a technographic approach enables the researcher to assume a descriptive stance rather than a normative one. Instead of condemning any departure from scientifically prescribed best practice as a fault or shortcoming that needs to be explained and corrected, the key goal is to understand and appreciate farmers' reasons for performing farming in particular ways. A technographic approach thus helpfully separates analysis from prescription.
>
> (*Glover 2011: 218*)[5]

Such an approach requires the consideration of social and institutional factors not as adoption constraints, but as a part of the socio-technological system that ultimately influences agricultural practice and production. Ekboir et al. (2002) explains that networks of agents (inclusive of research institutions, innovative farmers, the private sector, and donors) co-evolve with the technologies that they create, and it is these interlinked changes in agricultural practice, innovation and actors that is characteristic of a socio-technical system. It recognises that observed productivity benefits associated with a project of technology promotion, may be linked not just to the technical performance of particular practices or methods, but also to the information exchange, innovation, institutions and social capital that are intrinsic parts of these programmes. Whilst these might be positive impacts in well-designed and implemented programmes, they can also be negative.

From a technographic perspective it may be appropriate to further broaden out conventional understandings of what 'climate smartness' represents, such that it looks beyond the properties and appropriateness of particular technologies towards the way that broader socio-technical systems are changed and transformed. In the following section, the idea of CSA as the establishment of enabling environments – as positive socio-technical system change – is considered with reference to examples of agricultural development that reflect this broader agenda. Such approaches sit at the other extreme of this spectrum of flexibility, allowing for multiple rationalities to negotiate what it means to be 'climate smart' and co-designing the ways in which this plays out in practice.

Opening up to ambiguity in climate smart agriculture

Developing climate smart socio-technical systems inevitably requires a focus on complex and broad system dynamics: the social interactions of farmers, communities and extension services that shape multiple rationalities; the part that institutions, markets and infrastructures play in constraining and enabling agricultural decision-making and practice; and the processes by which researchers, farmers and donors innovate, adapt and co-develop agricultural technologies. Where 'climate smartness' is considered to be a condition of the functioning of this system, agricultural development becomes a task that is multi-sited and flexible with greater emphasis given to the processes by which agricultural systems are created – participatory research, information exchange, social learning and co-design – rather than on narrowly or predefined ideas about agricultural practice, technology usage and outcomes (see Box 6.1).

BOX 6.1 NON-TECHNOLOGICAL CSA

- Participatory Research
- Improving Information Access
- Knowledge Sharing Platforms
- Enabling Policies
- Institutional Capacity Building
- Women's Empowerment
- Promoting Autonomy and Informal Systems
- Access to Enabling Markets

FIGURE 6.1 Alternative agroforestry systems. Top: maize intercropped with lines of gliricidia sepium, a multi-use forage tree legume. Bottom: maize grown underneath a canopy of faidherbia albida, a fertiliser tree.

Photo Credit: World Agroforestry Centre Archives. Reproduced with permission.

Constructivist theories of knowledge and scholarship on transformative or 'farmer-first' adaptation, largely endorse participatory approaches to research and innovation, as a means of social learning, and the development of effective and resilient systems (Chambers et al. 1990, Osbahr 2007). Participatory approaches to research focus on the integration of the localised and experiential knowledge of real-world systems of farmers into innovation processes. In response to the rise of the participatory agenda, CGIAR institutions integrated and institutionalised innovative practices of participatory breeding and varietal selection within their crop-development strategies (Morris and Bellon 2004), with the aim of both better targeting the needs of the poorest farmers and improving the uptake of end- product technologies.The Africa Maize Stress (AMS) project, described in Chapter 5, represents a manifestation of this participatory research agenda, directly involving farmers in the trialling and evaluation of maize lines. A range of innovative participatory research processes have been developed and institutionalised within CIMMYT and other CGIAR centres. Brummett and Jamu (2011) similarly out- line the importance of farmer integrated research in a process of 'in situ' innovation in the World Fish Centre's integrated agriculture-aquaculture project in Malawi, and explain the importance of knowledge sharing and building around a technical and localised agricultural system. Although in some cases this focus on participation has been compromised by impact-at-scale agendas, in a movement away from expert monopolisation of agricultural innovation, the participation of 'local' or farmers' knowledge within research processes has also come to be seen as a key component of the development of climate smart agricultural systems.

Information provision and access represents a significant constraint on the capacities of small-scale farmers to participate in processes of innovation, both on- farm and within formal research and development (Bryan et al. 2009). Whilst improving the accuracy and reliability of information is important, as discussed in the case of improving climate-crop forecasts in Chapter 2 – and improved information quality is one of the main justifications of participatory research – effort is also being focused on access, and ability to interpret and act on information, within projects that range in scope from strengthening agricultural extension systems to developing climate services. The Ghana Environment and Climate Change Policy Action Node, funded through the Alliance for a Green Revolution for Africa and in collaboration with the Ministry of Food and Agriculture, is developing a set of national agricultural extension guidelines that will focus on improving the coordination and delivery of extension services to smallholders. National meteorological centres, often working in collaboration with international research and knowledge exchange organisations (such as the Hadley Centre CSRP, CCAFS, and the Humanitarian Futures Partnership) and donors are increasingly working to develop climate services that target timely, location-specific and clearly communicated climate forecasts as well as training farmers in the interpretation and use of probabilistic seasonal forecasts (Tall et al. 2014). The Climate Services Adaptation Programme in Africa, which is a collaboration between a number of research and development organisations – including CCAFS, the Centre for Climate and Environment Research, the World Food Programme and the Red Cross – is investing in the development and delivery of locally relevant information on climate hazards and risks using best available climate science in combination with local knowledge.

Whilst these, and many similar projects, are undoubtedly important in building local capacities for innovation and autonomous adaptation, their participatory component is often weak. There is a tendency towards the uni-directional flow of improved information rather than an engagement of localised knowledge in a process of co-construction or facilitating participatory research. The establishment of knowledge-sharing platforms that facilitate the sharing of experiences of practice from across locations, by contrast, is a direct response to recognition of the value of co-constructed knowledge. The Community for Climate Change Mitigation in Agriculture, organised by the FAO, and the Climate Change Adaptation and Mitigation Knowledge Network (AMKN), created by CCAFS, are two examples. AMKN is an online map of multimedia and multi-disciplinary information including cases studies and agricultural and climate data designed for use by practitioners, donors, policy-makers and researchers.[6] The Community for Climate Change Mitigation in Agriculture is a network of over 600 members, which predominantly interacts online, through discussion groups and online learning programmes (such as the 2013 programme on agroforestry which had 250 participants), and through social media.[7] The FAO also maintains a record of applied technologies and practices of smallholder farmers and provides information and a forum for discussion through its TECA exchange groups.[8] Such platforms, which are generally online, are nevertheless subject to a degree of exclusivity as they are of limited accessibility to rural and resource poor smallholders, who largely remain as recipients of information via those practitioners and extension workers that are able to engage.

Utilising and strengthening existing informal and social systems as platforms for knowledge exchange and social learning represents an complementary endeavour that focuses on an alternative means of participation (Kiptot et al. 2006, FAO 2013). Informal seed systems – on-farm seed saving and local farmer-to-farmer exchanges – for example, have been recognised as valuable mechanisms for con- serving crop genetic diversity, fostering innovation, and providing a means of access to seed inputs (Almekinders et al. 1994) as well as interactions in which there are often high levels of participant trust. Engagement in social learning through such systems, such as the integration of local germplasm within seed development initiatives or building on social networks for information spreading, has the potential not only to improve quality and access to knowledge, but particularly where farmers are directly engaged as participants in the knowledge-sharing community, to contribute to the building of social capital, innovation and empowerment.

The Uganda National Farmers Federation is a union of local and social net- works in which farmers participate to gain political representation, a social and financial safety net, and a means towards engagement in information exchange. In their CSA sourcebook, the FAO herald the federation, and a series of participatory workshops on 'Climate Adaptive Approaches to Food Security' organised through it, which have resulted in regionalised processes of agricultural system design, agricultural extension and demonstration, with an emphasis on identifying locally appropriate climate change adaptation measures and appropriate networks of extension and communication.

However, that participatory processes are not necessarily inclusive or empowering, and in some cases act to exclude certain voices, is a much-rehearsed and verified argument (Cooke and Kothari 2001). The marginalisation of women, in terms of decision-making power and access to resources and information, often as a result of gendered labour burdens and household responsibilities, has been particularly well- documented (Cornwall 2003, Chaudhury et al. 2012). Addressing these particular exclusions has been the focus of efforts to monitor and evaluate women's participation and resource control (e.g. in the case of IFPRI's 'Women's Empowerment in Agriculture Index') and to specifically target gender equality in the delivery of information and the design of knowledge exchange opportunities (Bartels et al. 2013).

When one considers CSA as being characterised by participation, empowerment, social learning, innovation, and the opening up of multiple pathways of agricultural change, barriers to climate smartness are comprised not simply of constraints on technology adoption, but of systems of governance, institutions and regulations that limit participation or close down agricultural pathways of change. National level agricultural investment and priority settings, research and development initiatives, commercial input production and pricing, agricultural extension services and advice, and output markets, not only act to shape and constrain farming systems, but are intrinsically related to, and constrained by, each other, such that decisions, and decision-making processes, at one level can set the boundaries of those at another. There is a conventional tendency for path dependencies in the governance of agri-food systems to be created around agricultural technologies. This convention begins with the development and definition of technologies, in more or less participatory ways, and then seeks to reduce adoption constraints, generate input and output markets, and push for enabling regulatory and policy environments – as is exemplified in the case of WEMA's lobbying around national biosafety regulations in Kenya, which is returned to in the final chapter.Targeting participation and inclusive governance across this whole value chain of interconnected decision-making requires a shift away from the conventional tendency for agricultural technologies to be at the centre of this governance process.

Representative of a decentralised and whole value chain governance of agricultural development, the Ghana Grains Partnership is described by Guyver and MacCarthy (2011) as an example of a market-led whole value-chain approach to promoting agricultural growth through a collaboration of public and private sector agricultural organisations, market regulators, buyers and traders, and donors and lenders and farmer grain associations that 'promotes participation and strategic dialogue among partners; shares ownership, risks and opportunities; identifies common objectives, needs and priority actions; introduces best practices; and builds and implements investment plans involving all major partners' (pp. 35–36). Examples of such approaches are limited, and seldom involve a systematic dialogue around climate information and what it means to be 'climate smart'; a point that is discussed further in the final chapter.

Broadening out a conceptualisation of CSA beyond the development, adoption and adaptation of technologies to focus on governance, access, capacities and decision-making across the whole value chain of agri-food systems, in theory, helps to overcome some of the pragmatic challenges of inappropriate technologies and disadoption that are often associated with the former, and recognises the importance of giving a voice to multiple knowledges and rationalities in the ongoing negotiation of agricultural practice. However, participation in cooperatives and platforms, just as it is in technology promotion schemes, is subject to limitations and barriers. Programmes of governance, just as in programmes of technology, can be vulnerable to elite capture and the closing down of alternative pathways or rationalities. The evaluation of such programmes therefore must necessarily be on procedural fairness and inclusiveness, rather than solely on outcomes, as continues to be the convention in CSA; e.g. total productivity (as in the stated aims of the Ghana Grains Partnership); or sequestered carbon.There is a danger that this out- come focus is encouraged by funding mechanisms, whether it is the impact-at-scale targets of international donors or new market-based climate financing. Specific climate financing mechanisms that are largely oriented around carbon sequestration/ storage monitoring and certification – such as in REDD+ voluntary carbon schemes – remain limited sources of CSA and arguably promote techno-centric schemes due to their reliance on quantifications of carbon storage effects and standardisation. Leveraging donor support for programmes of participatory research, developing knowledge-sharing platforms, increasing the accessibility of information and strengthening informal systems, for example, will depend not only on the recognition of the virtues of these activities, but in their mainstreaming as impactful fundamentals of CSA, or of future paradigms and priorities in agricultural development.

Discussion

As argued in previous chapters, there is a certain level of self-reinforcement between the development of technology-centred pathways of agricultural development and evidence bases that are designed and built around demonstrating the superiority of these technologies and practices over their conventional counter- part. Similar accusations of bias can equally be targeted at endeavours that set out to disprove or delegitimise success claims. Whilst controlled and on-farm field trials play a key role in the development and improvement of technological practice, they represent an incomplete and readily manipulated science, from which it is often inappropriate to make grand claims about societal impacts or the imperative rationality of technology adoption/disadoption. Such claims are justifiable only from a perspective that is narrowly techno-centric.Where recognition of the multiple and changing socio-economic constraints and drivers, agro-ecological conditions, and priorities and rationalities of farm systems is absent from their conceptualisation, simple comparisons between two or more manufactured simulations of agricultural practice come to be seen as rational (or, more problematically, objective) bases from which to advocate an agricultural technoogy as 'climate smart'.

Counters to narrowly conceived narratives of technological futures unsurprisingly emerge in the form of alternative strategies, technology disadoption, and political and regulatory barriers, as the multiplicity of local conditions, knowledge and rationalities come to bear within agri-food systems. Opening up processes of innovation and governance to these multiplicities – to uncertainty and ambiguity – requires a movement away from a techno-centrism that has become somewhat of a cultural convention of agricultural development, and one that is undoubtedly reinforced by funding mechanisms, donor priorities and impact-at-scale agendas. Even within platform technologies, which represent an important mechanism for facilitating on-farm innovation and adaptation of practices to suit local conditions, one commonly encounters statements about 'correct' practice, standard definitions, 'non-negotiable', and rates of adoption.

Limited consideration with agricultural research has been given to climate smartness as a condition of farms as socio-technical systems, such that the CSA label is attached to the processes and interactions of knowledge and practice as opposed to static and narrowly defined technologies. This broadening out of the CSA concept involves a shift away from thinking about optimisation, productivity and adoption targets, towards engaging in a more philosophical thinking about knowledge, the way that technologies are developed, and the role of technology development in a broader and more ambiguous system of interaction and practice. It requires a movement away from expert ownership of knowledge and innovation towards support for 'farmer-first' adaptations and undefined outcomes. In this chapter it has been suggested that a climate smart system is characterised by participatory research and innovation, improved information access and knowledge sharing, enabling markets and policies, and social empowerment, rather than the adoption of preconceived agronomic practices and principles.

There is some indication that such socio-technical processes and activities are becoming increasingly central to agricultural development programmes that target climate change adaptation and mitigation, and food security. However, even within such programmes, it is not uncommon that participatory processes and holistic governance mechanisms become oriented around specific technologies and agendas; that certain individuals and knowledge systems dominate the negotiation of agricultural futures; and that alternatives become closed down or marginalised. Knowledge claims and contested evidence bases transcend this unavoidable politics, which takes place at all scales of innovation and governance. Drawing on the multiple cases, projects, sites and incomplete knowledges explored throughout this book, the final chapter considers in more depth the challenges and opportunities of negotiating agricultural futures.

Notes

1. Available at www.push-pull.net/3.shtml (accessed December 2014).
2. Reprinted with the permission of Elsevier.
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4. Available at www.worldagroforestrycentre.org/our_products/databases/useful-tree-species- africa (accessed December 2014).
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CHAPTER 3

Alternative Configurations of Agronomic Experimentation

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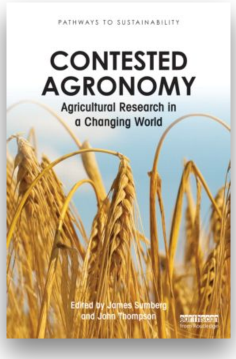

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Harro Maat and Dominic Glover

Introduction

The emergence and spread of the System of Rice Intensification (SRI) have stimulated heated controversy among rice scientists and development workers. SRI is a method of rice cultivation that is said to produce high yields while also conserving natural resources, especially water. Claims that dramatically increased yields can be achieved with SRI, in some cases exceeding what plant physiologists consider to be the yield ceiling for rice, triggered hostile responses from some scientists. Promoters of SRI argue that it is superior to existing cultivation practices, and has particular advantages over the technology packages associated with the Green Revolution. Many within the rice research establishment dismiss SRI as a combination of well established 'good management' practices and some extraordinary claims that cannot be substantiated or replicated. Proponents of SRI insist that remarkable results are being achieved in farmers' fields, and point to the enthusiasm of both farmers and non-governmental organisations in using and spreading SRI to rice-growing regions around the world (Berkhout and Glover 2011; Glover 2011).

Until recently, the SRI dispute has been conducted largely as an argument about the best methods for cultivating rice. In this chapter we take a different tack and argue that the controversy surrounding SRI exemplifies a more general and fundamental disagreement about how agronomic research on rice should be organised and pursued.

To develop our argument, we examine the nature of experiments in agronomy. The design and conduct of agronomic experiments serve to configure the relationship between the worlds of scientific research and agricultural practice. This relationship is fundamentally concerned with the generation and transmission of information, knowledge and techniques. In principle, these can flow in both directions – from the laboratory and field station to farmers' fields and *vice versa*.

The relationship between formal science and farming practice can be configured in different ways, however. Here we examine the historical processes that have led to the evolution of particular configurations of this relationship, which are associated with a bifurcated division of labour in agronomic science between researchers and agricultural extension agents. As an intrinsic part of this organisational partition, the two branches of the profession developed different methods for structuring their relationships with farmers. We argue that because of this division of labour, in different times and places the relationship has been configured in ways that have tended to privilege the flow of information, knowledge and technology in one direction rather than the other.

We use the example of SRI to show that the discontinuities between the two aspects of professional agronomy and their characteristic methods and approaches continue to exist. These discontinuities helped not only to shape the technical content of SRI, but also to fuel the passionate disputes that surround it. We show that SRI emerged in relative social isolation from the international mainstream of rice agronomy. Consequently, it was developed using a particular style of scientific practice, which helped to produce a distinctive set of rice cultivation methods. In particular, we draw attention to the organisation of the field-level activities and practices that led to the development of SRI methods, including the social and institutional setting within which those developments occurred.

Experiments in agronomy

Most agronomists would agree that an essential feature of agronomic science and expertise is their applied and practical nature. Agronomy is not just about biological, chemical and physical processes and relationships, but is integrally concerned with farming practice, skill and technique. For agronomists, foundational research on topics such as soil chemistry, plant physiology and crop growth modelling is valuable only when outputs are tested, monitored, evaluated and applied in real production conditions.

Experimentation plays a crucial role in connecting the academic discipline of agronomy with agricultural practice. Historically, there is a strong argument for considering 'experimental turns' in two antecedent disciplines, organic chemistry and biology, as key moments in the development of agronomy as a distinct discipline. For organic chemistry, this goes back to the work of Justus von Liebig, whose experimental approach, developed in Germany in the 1820s and 1830s, gave impetus to the work of agricultural research stations worldwide (Rossiter 1975). A few decades later, Charles Darwin's work forged an experimental connection between biology and agriculture. Darwin himself pointed out that plant and animal breeding mimicked evolutionary processes, and his theory of evolution provided a scientific basis for experimental research in plant breeding and plant physiology (Kimmelman 1987; Cittadino 1990).

Agronomists and other agricultural scientists generally draw a distinction between experiments and demonstrations. Experiments are usually seen as having an objective to discover facts or principles, generate data, test hypotheses, determine causes or confirm theories. They are designed by, and primarily for, professional researchers. Experiments are understood as methods for systematically comparing two or (more typically) more 'treatments' or sets of treatments, using designs (including replications, plot sizes, plot arrangements, spatial placement, etc.) that allow systematic data collection and rigorous analysis of the statistical significance of treatment effects and interactions. Many agronomic field experiments are undertaken to provide information that can be fed into the development of new production methods and technologies.

Demonstrations, on the other hand, are usually seen as having an objective to demonstrate, convince or persuade. They typically have a simple format with perhaps only two treatments, a straightforward side-by-side comparison, and often little formal 'analysis'. They are generally conducted by extension officers or company representatives, often with the cooperation of a farmer, for the purpose of disseminating new knowledge and practices that have already been discovered, developed and refined by scientists. This distinction between experimentation and demonstration reflects a specific perception of the relationship between science and practice, a perception that underpins the basic division of labour seen in present-day professional agronomy and the different approaches to field-based activities.

However, it is not at all unusual or misleading to apply the term 'experiment' to pedagogical exercises designed to demonstrate phenomena that are already well known – school science lessons being an obvious example. Studies in the history and sociology of science and technology show the long-standing dual role of experiments – as instruments of scientific discovery and as methods of instruction and persuasion. Experiments as well as demonstrations represent the key means by which science and its publics (including users of scientific knowledge, such as farmers) have been linked.

An early example is given by Steven Shapin (1988), who describes the activities of Royal Society Fellows in seventeenth-century England. To gain acceptance for the observations they made and the theories they developed, it was not enough for these early scientists merely to attend to their instruments and apparatuses. Much of their time and energy was devoted to what is nowadays called social networking, specifically the arrangement of an appropriate audience of influential people before whom, during carefully choreographed social events, they would replicate experiments that they had previously refined in their workshops. The experiments themselves had to be designed, as well as explained, in such a way that they would convince such an audience.

A similar point is made by Bruno Latour in his account of Louis Pasteur's work on the anthrax vaccine. While it was relatively easy to make the vaccine work in the laboratory, the real challenge was to convince veterinarians and livestock farmers of its value. To achieve this, Pasteur organised 'demonstrations' on a farm in France that were designed 'to bring to the still uncertain public a fresh and more grandiosely staged proof of the efficacy of the vaccine' (Latour 1983: 152). In this way, the French veterinarians and farmers were bound together with Pasteur's microbiology laboratory. This connection, Latour argues, is not simply about research results being disseminated to the livestock industry, but is about the creation, by means of an experiment, of a mutual dependency between all the actors involved, creating an 'actor-network' in which the laboratory forms a central node. Within the actor-network, not only Pasteur but also veterinarians and farmers (not to mention livestock, microbes and vaccines) had their roles to play.

The work of Shapin and Latour makes clear that there is only a thin line between experiments designed to test hypotheses and demonstrations designed to convince a selectively targeted audience. For researchers, the key to success lies in mobilising support from a larger set of actors, and experiments (including, for our purposes, demonstrations) play a central role in this effort. It is the type of audience to be convinced that largely determines the design and arrangement of the experiment. Those to be convinced may encompass a wide range, from the scientist's immediate colleagues within a laboratory or institute to a much wider public outside it. Because of its applied nature, agronomic science is not an activity conducted entirely behind the fences of research stations; through experiments and demonstrations, it is also carried out in public view.

Shapin's and Latour's analyses of scientists' activities in the seventeenth and eighteenth centuries apply equally to contemporary scientific practice (Latour 1987). This point is underlined by Levidow and Carr (2010) in their discussion of the way field trials of a controversial technology such as genetically modified crops are amenable to a variety of interpretations by different stakeholders. These trials can be simultaneously demonstrations of the technology's efficacy and safety; tools for identifying risks and hazards; ways of modelling the behaviour of farmers, crops, insects and weeds; and politically charged orchestrations intended to persuade reluctant consumers to accept an unpopular technology. In a similar vein, Glover (2007: 165) found that the staff of a commercial agribusiness company that was attempting to develop a market for genetically modified seeds in India 'did not draw clear distinctions between a trial as a safety assessment for regulatory purposes, as a pre-commercial performance evaluation on a new proprietary crop variety or as a demonstration plot to be used as a marketing tool'. Experiments and demonstrations help to establish a connection between science and practice through a site-specific process of network building, in which the skilled activities of various actors play crucial roles. One such role is played by professionals who mediate between basic researchers and the eventual end users of their work. In the case described by Latour, it was veterinarians who helped to connect Pasteur to cattle farmers. In agronomy, this role is usually played by agricultural extension officers.

The intermediary role of agricultural extension is not just about disseminating knowledge from the laboratory to the field. In his account of field trials conducted in California, Henke (2000) shows that the quality of the experimental results depended on the skilled work of a variety of different actors, not just scientists. In particular, extension officers played a key role in mediating between scientists, farmers, field technicians, farm labourers and company representatives. Henke also shows that crucial parts of the experimental work were done by Mexican immigrant fieldworkers, whose farming skills were vital in securing the data: 'Through their harvest skills, these fieldworkers not only help advisors [extension officers] make their trials more "lab-like", by standardizing the collection of data, but also more "field-like", by helping them get the right kind of data' (Henke 2000: 500).

Extension officers must work closely with farmers in order to bridge the gap between science and practice. Moreover, farmers themselves have skilled work to do in order to translate scientific information into farming methods that are adapted to their own conditions. An agricultural development project implemented in East Timor illustrates both the involvement of farmers as key actors in the successful generation and dissemination of knowledge and technologies, and the dual nature of on-farm experiments. In the Seeds of Life programme, farmers performed a central role in the management of 'on-farm demonstration trials' – the combination of 'trial' and 'demonstration' is significant – that 'served a double purpose: as a testing ground for seed germplasm performance and, simultaneously, as an agricultural extension strategy whereby the improved seed could be disseminated through local channels' (Shepherd and McWilliam 2011: 204).

Just as agronomists must engage with the world of practice, anthropological studies show that farming practice also involves experimentation. The designers of the Seeds of Life programme drew explicitly on anthropological insights and deliberately enrolled farmers as full participants in the project in order to achieve its goals. The anthropologist Paul Richards (1989a, 1989b) has shown from his studies of rice producers in Sierra Leone that agricultural practice is intrinsically experimental. Other scholars and practitioners have also explored the nature of farmers' experiments and confirmed farmers' capacity to frame research questions, try out interventions and engage with scientists' experimental methods (Sumberg and Okali 1997; van Veldhuizen et al 1997). Examples like these demonstrate the importance of building effective connections between formal science and farming practice. The key challenge is how best to configure those connections.

The emerging gap between science and practice

In the previous section, we cited several examples which show that the social worlds of science and practice may be connected by means of a range or continuum of different field activities – including experiments and demonstrations – which combine knowledge generation and dissemination in locally, historically and topically specific ways. In this respect, agronomy is no different from other science disciplines. The distinction that modern agronomy makes between experiments and demonstrations results from the particular way that this continuum has been divided conceptually, professionally and methodologically. To further develop this argument and to explore how this partitioning occurred, we examine the case of agricultural science in the Netherlands and its former colonies.

During the second half of the nineteenth century, the nascent agricultural sciences in the Netherlands faced a growing demand from below in the form of farmers' associations seeking (and paying for) scientific advice. From above, governments invested in agricultural research and education to stimulate the agricultural sector (Marcus 1985; Maat 2001; Harwood 2007). The emerging agricultural research stations, schools and universities offered support to the farm sector through demonstration plots, school gardens and field experiments. These diverse activities were the main source of information for farmers and researchers alike. Their information needs differed, however: farmers sought reliable information with which to improve their practices, while agronomists sought a reliable basis from which to make appropriate generalisations and provide good advice.

However, researchers soon realised that simply trying a farming method or technology and observing the result during a single season was not appropriate, primarily because of site-to-site and season-to-season variability. By the end of the nineteenth century, many agronomists were aware that replication and inference calculation or statistical significance testing could help solve this problem, but several decades passed before appropriate methods were developed and applied in a standardised format. A professor of statistics was appointed at the Agricultural College in Wageningen in 1913, but for many years there were still no guidelines or handbooks that provided extension officers with agreed methods for the design and analysis of field trials (Gigerenzer et al 1989; Maat 2008).

As they struggled to find the best way to generate reliable information that would meet their respective needs, differences began to open up between agricultural researchers and extension officers. In the early 1910s, for example, the agricultural chemist Joost Hudig criticised Dutch agricultural extension officers for lacking a proper under- standing of the mathematical complexity of experimentation. His main worry was the extension officers' habit of combining experiments from different locations and drawing conclusions based on averages calculated over locations (Hudig 1911, 1912). In a response to Hudig, one extension officer explained that he felt 'morally obliged' to inform farmers about results of trials even if they did not follow the latest scientific norms (Rauwerda 1913).

In the mid-1920s, the Ministry of Agriculture created a committee to develop guidelines for the conduct of field experiments. The committee found that not much had changed since the 1910s. The chairman complained during a conference that field trials were not real experiments but demonstrations, which were not carried out according to 'the new scientific methods of experimenting' (Koeslag 1922). Several extension officers responded to his presentation, emphasising the value of demonstrations which, they argued, helped farmers to get a vivid impression of the effects of particular treatments.

The committee took several years to arrive at an agreed position, which was turned into a manual for agronomic field activities that was published by the ministry. The manual distinguished between five different types of activity: (1) demonstrations of clearly observable differences; (2) observation experiments for disease resistance; (3) exploratory experiments to determine which factors needed more precise testing; (4) experiments where 'yield was the decisive element'; and (5) 'institute experiments' to be conducted at research stations and not suitable for farmers' fields (Landbouwvoorlichtingsdienst 1934).

The manual's five categories are remarkable because they reflect the committee's perception that there should be a range of activities in the space between the worlds of science and practice. However, while the committee had been deliberating, research stations and extension services had grown in size and, despite the central coordination exercised by the Ministry of Agriculture, evolved into different kinds of institution, each with its own organisational features. It was this organisational differentiation, together with the adoption of particular methodologies for different types of field activities, that helped to entrench the distinction between experiments and demonstrations which has persisted to the present day.

Guided by the work of Ronald Fisher and other statisticians, professional agronomic researchers in the Netherlands, like their counterparts elsewhere, increasingly understood that the meaning and significance of experimental results could became apparent only through the application of controlled and randomised experimental designs and the use of sophisticated mathematical techniques (Gigerenzer et al 1989). Such designs and analytical methods not only made it possible to be much more confident that an observed result could be attributed to a given treatment, they also allowed researchers to identify subtle effects and interactions that were not visible to the naked eye.

Extension officers, on the other hand, knew that farmers were most likely to be convinced by vivid demonstrations, whether these could be directly observed in the field or in easily grasped numbers. Over-elaborate experiments might alienate the very farmers who were supposed to benefit from them, while subtle or invisible effects might not be very persuasive. Over the years, extension officers have become increasingly preoccupied not with the rigour of experimental designs as such, but with identifying effective methods of communication, measuring the impact of extension systems, promoting knowledge exchanges and stimulating innovation processes (Leeuwis and van den Ban 2004).

The emerging division of labour between research and demonstrations was not accepted by all agronomists, however. A clear example can be found in the activities of Dutch agricultural officers in colonial Indonesia.

By and large, the graduates who were employed as agricultural extensionists in the Dutch colonies were agronomists with some training in social science disciplines, primarily agricultural economics (Maat 2001). Extension officers in the Netherlands Indies faced the challenge of setting up extension activities for a type of agriculture with which they were not familiar. Establishing a basic understanding of agricultural practice in the region was a core element of their activities.

In 1947 one of these Dutch extension officers, W. J. Timmer, proposed an integrated methodology for agricultural research and extension based on empirically driven field research incorporating both plant and social sciences. Timmer called this model 'social agronomy' and argued that its foundation should be a detailed appraisal of the rural area: 'the principle "know your district" is a crucial requirement for every social agronomist and, if this is not met, appropriate extension is out of the question' (Timmer 1947: 176).

Timmer proposed a step-wise procedure: after collection and analysis of information, research topics were to be prioritised, after which cultivation practices, treatments or techniques would be tested and disseminated. In practice, advisors were occupied primarily with the last phase – testing and promotion. Research institutes put pressure on the extension service to disseminate their findings and as a result extension officers had little time for an elaborate exploratory phase. Timmer complained that this meant the introduction of new cultivation methods or technologies was often based on little more than 'a good guess' (Timmer 1947: 182). In place of this, Timmer wanted to make agronomy speak to the locally specific conditions of farmers, not by intensifying the downstream flow of information, but by creating a broad and integrated exchange of information between the field and research institutes.

Timmer's interest in social agronomy was not unique. The importance of empirical field research was stressed by other colonial agronomists, such as Pierre De Schlippe in central Africa (Richards 1989a) and Jean-Paul Dobelmann in Madagascar (Dobelmann

1961). Even earlier, René Dumont (1935) in Vietnam realised that farmers themselves needed to carry out their own experiments in order to work out locally adapted farming methods. The concerns of these colonial-era agronomists resurfaced in later decades, perhaps most prominently in the form of farmer participatory research and participatory plant breeding and varietal selection (Okali et al 1994; Almekinders and Elings 2001).

More recently, some scholars have proposed new institutional and methodological arrangements that would involve an even more profound rebalancing of the relationship between farmers' experiments and the experimental practices of agricultural scientists, while enlarging the base from which knowledge can be generated and disseminated. As we noted above, the Seeds of Life programme in East Timor deliberately harnessed the knowledge, experimental behaviour and social networks of farmers in both seed selection and the dissemination of improved, locally adapted seed varieties (Shepherd and McWilliam 2011). Richards et al (2009) have taken this kind of design to a new level, with a proposal to exploit the power of 'unsupervised learning' among a large number of farmers, modelling on artificial neural networks. In a similar vein, van Etten (2011) has offered detailed proposals for exploiting the potential of 'crowdsourcing' in crop improvement programmes.

These proposals seek to mobilise the knowledge, skills and experimental behaviour of farmers themselves, in order to achieve outcomes that are both meaningful to science and readily applicable in farmer practice. In doing so, they seek to broaden the locus of knowledge generation and transform the flow of technology dissemination, by acknowledging farmers as crucial partners in both of these activities. Although we do not have space here to describe the proposals in detail, we simply note that they seek to accomplish these objectives by deliberately blending different approaches to experimentation and technology dissemination. They also accept that institutional separation of research and extension is a historically contingent fact rather than an intrinsic feature of agronomic science, and seek therefore to rethink the division of labour between researchers and agricultural extension officers.

In the next sections, we consider the case of SRI as an illustration of our argument. Both SRI and the controversy that surrounds it serve to illustrate the continuing disconnection between formal agricultural research, extension and farming practice. The case of SRI also illustrates our argument that agronomic science, technological innovation and changes in farming practice occur through historically situated and contingent engagements between farmers, extension officers and scientists, where the experimentation and demonstration functions are not neatly separated.

The emergence of SRI

SRI is a method of rice cultivation which involves a number of principles or practices that can be concisely summarised as follows: the transplanting of single, very young, widely spaced seedlings; irrigation using very limited amounts of water during the vegetative growth period, sometimes including short periods when the soil is allowed to dry; and careful control of weeds, ideally by disturbing the soil so as to increase aeration. Application of substantial quantities of organic fertiliser is encouraged in order to stimulate microbial activity in the soil.

These principles are said to allow rice plants to achieve significantly higher levels of growth and grain yield, while consuming much less water. SRI's advocates position it as an agro-ecological, low external-input farming method, which is peculiarly accessible to resource-poor farmers since it does not require the adoption of new rice varieties or expensive chemical inputs (Uphoff 1999, 2003, 2007; Stoop et al 2002; Mishra et al 2006).

SRI was first elaborated by Father Henri de Laulanié, a French missionary of the Catholic Jesuit order who earned a diploma in agronomy from the National Agronomic Research Institute (INRA) in Paris. When he was sent to Madagascar in 1961, de Laulanié was unfamiliar with rice and therefore depended heavily on his own observations and the handful of manuals and handbooks available to him. He examined rice plants closely, studied their growth patterns in detail, and paid attention to the cultivation methods he saw being used by Malagasy farmers, including atypical practices he observed in certain locations. One year, he observed something remarkable that was not explained by the information available in his handbooks: rice seedlings transplanted at only 15 days old (a strategy to cope with an early season drought) seemed to grow with surprising vigour, leading to a higher grain yield.

Unfortunately, in the Madagascar of the 1970s and 1980s, de Laulanié was largely cut off from any agricultural research or extension system that could either provide him with scientific advice or incorporate his observations and experiences into existing research programmes. He seized upon the few sources of scientific information that came his way and, in the absence of more systematic support, he relied heavily on the simple trial-and-error experiments carried out by students in his own training fields. His professional judgements were informed not only by his agronomic training, but also by his experience and intentions as a development worker. The local success of his inductive scientific methods depended on close engagement with small-scale Malagasy farmers and on his combined status as scientist and priest (Berkhout and Glover 2011; Glover 2011).

SRI as contested agronomy

The disconnection between de Laulanié's inductive scientific practice in the Madagascar highlands and formal agricultural research helps to explain not only the nature of the rice production system he devised, but also the controversy that surrounds it today.

Since de Laulanié had based SRI partly on field manuals and on the physiological characteristics of rice, it is not surprising that some of the practices he advocated resemble aspects of 'best management practices' recommended by rice science institutions such as the International Rice Research Institute (IRRI). At the same time, because de Laulanié's scientific method was inductive, and because SRI was based on farmers' existing practices and optimised for a particular agro-ecological setting and community of farmers, it is also not surprising that SRI is somewhat distinct from the recommendations of mainstream rice science. Under the Green Revolution regime, international rice research and development were organised in line with a single, standardising template for rice improvement that took relatively little account of diverse local variations in growing conditions (Harwood 2009; Smith 2009). In contrast, the distinctive features of SRI reflect the special characteristics of the time and place in which it emerged, as well as the subjective judgements of the individual who played a dominant role in its development (Berkhout and Glover 2011; Glover 2011).

Together, these similarities and differences help to explain why SRI received a hostile reception from mainstream rice scientists when it began to spread beyond Madagascar in the late 1990s. How, they must have asked, could a missionary based in the Madagascar highlands have developed a method of rice cultivation that was superior to the systems recommended by the foremost national and international centres of rice research? The fact that SRI combined well established good management practices (such as the application of organic fertiliser) with unorthodox elements made this question all the more explosive.

The arguments for and against SRI published in agronomic journals confirm that the controversy is partly about rice biology and physiology, and partly about the proper organisation and conduct of agronomic research. Scientists associated with IRRI have dismissed SRI as a delusion based on mistaken theory and inaccurate measurement. Some of their most trenchant critiques of SRI have taken the form of theoretical and modelling analyses, using estimates based on existing scientific knowledge, which have led them to conclude that the claims made on behalf of SRI were implausible because they breached the known physiological limits of rice growth and productivity. The authors of these papers insisted that SRI had nothing to offer in the quest to increase the yield potential of rice, which, in their view, would require advanced biotechnology-based breeding methods (Dobermann 2004; Sheehy et al 2004).

In response, supporters of SRI argued that it was inappropriate to use scientific theory to dismiss remarkable empirical observations from farmers' fields; instead, it should be the role of agronomic science to investigate and explain these surprising field observations. Second, they challenged the IRRI scientists' implicit assumption that increasing rice yields should be the primary goal of rice research. They pointed out that what poor and marginal farmers really need is locally adapted and accessible cultivation methods based on the intensification of labour, rather than standardised high-yielding technology packages that depend on expensive external inputs. Indeed, SRI proponents have argued that it is spreading spontaneously from farmer to farmer and country to country precisely because of its intrinsic attractiveness and accessibility to resource-poor farmers (Stoop and Kassam 2005; Uphoff 2007). Third, SRI's proponents argue that conventional methods of evaluation are inadequate for assessing a technology whose most powerful effects are produced, they believe, through synergetic interactions among several different practices. They believe that these synergetic relationships extend the physiological potential of the rice plant, which explains why spectacular yield increases have been reported in farmers' fields (Uphoff 1999; Stoop et al 2002; Uphoff et al 2008). It is interesting to note that, with the latter two arguments, SRI advocates assert both that yield should not be the exclusive centre of attention, and that SRI can unlock a higher yield potential compared with conventional methods.

Although statistical techniques developed for field experiments typically test for effects within a single set of treatments (e.g. different rice varieties), depending on the experimental design, the interactions between different sets of treatments such as varieties and N fertiliser can also be analysed. Some of the data cited by SRI proponents to support their claims have been derived from rather simple side-by-side comparisons of rice performance under SRI and an alternative management practice. Unless such comparisons are designed and replicated very carefully, the interactions among variables and the benefits or disadvantages of particular practices or combinations of practices are impossible to discern (Berkhout and Glover 2011).

SRI's proponents take a different view, arguing that SRI represents a particular type of field-level innovation, discovered and developed through practical experience and grounded empiricism rather than formal scientific experimentation. They also suggest that the impact of SRI is crucially related to it having been grounded in situated farming practice, because it exploits the cumulative effects of a steady improvement in soil quality through the addition of organic fertilisers and altered water management practices. They argue that these features of SRI are liable to be systematically underestimated by short-term field trials carried out on research stations (Stoop and Kassam 2005).

By focusing on the practical experiences of farmers in this way, the advocates of SRI draw attention to the visibility of its effects as a key factor in its development and spread. While the impacts of SRI methods on yield and productivity continue to be disputed, one consistent observation is that SRI typically produces significant changes in the growth and morphology of individual rice plants, which are visible to the naked eye. The plants generally produce more luxuriant vegetative growth and often a large number of panicles. When the plants are pulled out of the ground, they often reveal long and visibly healthy root systems (Berkhout and Glover 2011).

In farmers' fields, this dramatic demonstration of the impact of SRI can create a powerful impression. Numerous photographs showing side-by-side comparisons of rice fields and rice plants grown under SRI and conventional management have circulated in cyberspace, creating a vivid impression of the difference between the two. Rice scientists pose questions about such images, however. They point out that the rapid and vigorous growth of rice plants grown under SRI does not necessarily or consistently lead to a higher grain yield. In particular, it has often been observed that there is a trade-off between planting density and the size and productivity of individual plants. For instance, when planted at low densities, individual rice plants tend to produce a large number of panicles per plant, but the number of panicles per square metre may not be any greater than with more densely spaced plants, even if these densely packed plants are visibly less productive on an individual basis (Angladette 1966).

Instead of having an impact on yield (land productivity), the most attractive effects of SRI may be a substantial increase in the productivity of other inputs, including seeds, water and even labour. Such benefits may be extremely attractive to poor rice farmers, perhaps even more so than an absolute increase in yield. However, these productivity effects may be subtle and apparent only at the end of the season, after reflection, measurement and calculation. To demonstrate such subtle effects, sophisticated experimental designs and statistical methods may be required; few of the studies published to date have met these standards (Berkhout and Glover 2011; Glover 2011).

Compared with such methods, the visual impression created by comparing obvious differences between two fields, plots or plants can be much more immediate and powerful. These visible differences appear to play a role in helping SRI to spread, often through the arrangement of demonstrations designed to show farmers that the system makes a clear, beneficial difference to the growth of individual rice plants. Such demonstrations work in the same way as the original observation of the growth patterns of young transplants that led Henri de Laulanié to develop SRI in the first place. In both cases, empirical observation of a striking phenomenon stimulates action.

A factor that makes the case of SRI particularly interesting is the extended network of organisations and individuals promoting it. In the cases typically analysed in the field of science and technology studies, network building is an activity generally initiated by scientists, laboratories and research institutes, while other actors such as entrepreneurs, companies and governments also play important roles. In the SRI case, a strong lateral network has emerged within and between countries and regions, involving not only research scientists, but also farmers' associations, non-governmental organisations and civil society groups, philanthropic agencies and others. SRI can thus be 'understood not merely as a set of crop management principles but as the fruit of a distinctive socio-technical system of knowledge and innovation that has operated, at least partly, outside the mainstream circuits of the international agricultural research system' (Berkhout and Glover 2011: 137).

This institutional characteristic of the SRI phenomenon may be one important reason for the dismissive responses of some scientists and research institutes. The bifurcation of professional agronomy into separate groups of research scientists and extension officers, the evolution of extension towards information dissemination and input distribution, and the establishment of the international agricultural research institutes in the 1950s and 1960s disrupted the channels for the upward flow of information from the field to the research station and the laboratory. The substantial stream of information generated by the SRI network thus confronted national and international research institutes with a difficult and unfamiliar task: how could this new information be related to their own knowledge and research practice?

Conclusion

Experiments and demonstrations of various kinds play a central role in agronomy, because they serve to configure the relationship between the worlds of scientific research and agricultural practice. Field experiments and demonstrations should both be understood as events conducted in specific historical, social and institutional settings, through which the knowledge and skills of various actors are mobilised and combined. Historically, however, different norms and standards have been adopted for experiments and demonstrations. True experiments are considered 'science-only' events for the generation or validation of new agronomic knowledge, practices and technologies. Demonstrations – which can include some kinds of field trials that have an avowedly investigative character – are seen primarily as mechanisms for promoting and disseminating these scientific products to farmers.

This division of labour and its linear, top-down information flow emerged from efforts to solve the practical problem of connecting agronomic research with farmers' practice. It became a standard institutional model, which was entrenched through choices made in the formal organisation of agricultural research institutes and extension organisations. Dissatisfaction with this model led some individuals and organisations to propose new ways of incorporating information and innovation generated at farm level, including social agronomy, participatory plant breeding and participatory varietal selection, crowdsourcing and unsupervised learning. However, these developed (or are now being proposed) only on the margins of mainstream agronomy.

The controversy over SRI demonstrates some of the continuing effects of the disconnection between formal agronomic research and field-level technology development and promotion. Our analysis suggests that a resolution of the SRI controversy will require the interests and activities of farmers to be connected to, and balanced with, the scientific requirements of researchers. The principal spaces where this is likely to happen are experimental and demonstration plots. It is here that the knowledge and practices of laboratory scientists, technicians, extension officers, field technicians, labourers and farmers can be combined and coordinated to improve the connections between scientific agronomy and farming practice.

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CHAPTER 4

Contested As Continuity? Biofortification Research and the CGIAR

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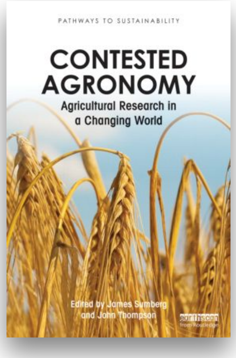

Introduction

Biofortification, the development of nutrient-dense staple crops, has been promoted both as a solution to 'hidden hunger' among poor populations in the developing world (Nestel et al 2006) and as an exemplar of the kind of global public goods research for which the CGIAR system is renowned (Dalrymple 2008). As an interdisciplinary field of research and development linking crop science with human nutrition and public health (CIAT and IFPRI 2002), biofortification presents both challenges and opportunities for an international agricultural research system oriented towards genetics-led crop improvement (Anderson et al 1991). This chapter traces developments in biofortification research over a fifteen-year period during which it emerged from the margins of the CGIAR to become a priority for research investment (von Braun et al 2008).

Biofortification is a relatively new term which simultaneously refers to (i) a range of technologies designed to alter the grain nutrient levels in selected crop varieties; (ii) a development intervention combining goals of improved public health and poverty alleviation; and (iii) an idea linking agriculture, nutrition and health in new ways. It is a multi-dimensional 'project' contested on a number of levels, in terms of its technical feasibility and efficacy (in controlled conditions), effectiveness and impact (in the 'real world'), and appropriateness and desirability (in comparison with alternative solutions). This chapter analyses developments in biofortification research as an extended case study in contested agronomy[1], in which a body of knowledge about complex interactions between genotypes, soils, human bodies and populations has evolved over time, in ways that have both reflected and reinforced particular sets of interdisciplinary and inter-institutional relations. In the process, certain types of knowledge have presided over others, with the result that some dimensions of this complex, multi-dimensional project have been contested, while others have not.

This chapter traces successive stages of biofortification research within the CGIAR and among its partners, highlighting how these dimensions of potential contestation have played out at each stage, in ways that reflected the priorities of the time, location and particular characteristics of crops, nutrients and technologies. Despite these specificities, certain continuities can be identified. In particular, contestation has tended to focus on feasibility and efficacy questions that can be resolved within the confines of institutional science, at the expense of broader questions about effectiveness and appropriateness in the context of the needs, priorities and programmes of particular countries and populations. A notable exception is the contestation surrounding the controversial 'Golden Rice' project, which has been elevated to exemplary 'case study' status in the GM crop debate (Jasanoff 2005; Taverne 2007). In the process, a multiplicity of uncertainties about the less emotive, technical aspects of the project have been shielded from professional as well as public scrutiny (Brooks 2010).

One dimension that has gone remarkably uncontested, at least by the international nutrition community, is the question of the appropriateness of biofortification as a nutritional intervention (although there are notable exceptions; for example, see Johns and Sthapit 2004). This may be because biofortification does not, for this community, represent a fundamental change of paradigm. Since the mid-1990s, the field has been dominated by a 'goal-oriented nutrition' paradigm that is particularly amenable to scalable micronutrient delivery mechanisms such as industrial food fortification and pharmaceutical supplements (Gillespie et al 2004; Latham 2010). From this position, biofortification, despite its novelty, does not represent a significant point of departure. Instead, debates about impact are dominated by *ex ante* analyses extrapolating health and economic outcomes associated with a 'switch' from non-biofortified to biofortified varieties (Stein et al 2005). By and large, these analyses are based on frameworks from neoclassical economics, which do not take into account the diversity of ways in which rice is cultivated, processed and consumed within different cultural and agro-ecological contexts (Brooks 2010).

A glance back at the CGIAR's firs biofortification project (long before the term appeared) suggests that this lack of debate about effectiveness and appropriateness, particularly with regard to addressing the nutritional needs of the poorest, was indeed problematic. Research began at the Mexico-based International Maize and Wheat Improvement Center (CIMMYT) on *opaque2* maize in the 1960s (Mertz et al 1964), providing the foundation for the Quality Protein Maize (QPM) programme that has continued from the 1970s to this day. Accounts of the trajectory of QPM research reveal repeated cycles of optimism inspired by each new 'breakthrough', only to be tempered by field results that were insufficiently conclusive to justify either full endorsement or closure (Mertz 1997; see also Prasanna et al 2001).[2] Today, QPM is grown extensively in East Africa, although the extent to which this is due to its nutritional qualities is uncertain (De Groote et al 2010). In India, the national maize breeding programme prioritizes QPM research (Prasanna et al 2001), although its work is increasingly oriented towards the livestock feed market rather than the nutritional deficiencies of the poor (Hellin and Erenstein 2009).

Will more recent biofortification initiatives, focused on the micronutrients iron, zinc and vitamin A, avoid these ambiguities and succeed in reaching the poorest? An example and oft-cited biofortification 'success story' has been the promotion of orange fleshed sweet potato (OFSP) in sub-Saharan Africa. Naturally high in beta- carotene (the precursor of vitamin A), its substitution for white-fleshed sweet potato has been a favoured food-based strategy of nutritionists for many years (Gichuki et al 1997; Hagenimama et al 2001; Low et al 2001, 2007). The untapped potential of OFSP to combat vitamin A deficiency led to the absorption of ongoing research activity into the HarvestPlus Biofortification Challenge Program as the basis for much of its early 'end-user' work.[3] In contrast to other crops targeted by the CGIAR for biofortification, the OFSP project utilises well developed products, the efficacy and desirability of which do not attract contestation. Nevertheless, questions remain about the effectiveness of a nutrition intervention, based on food items that still require intensive promotion, even after twenty years of research and development efforts.[4]

Perhaps because of the conspicuous yellow colour associated with the trait, research on biofortification of crops with beta-carotene has tended to have a higher profile than research focusing on other nutrients. Varieties enriched with beta-carotene exhibit a yellow-orange colour that makes it possible to segregate biofortified from non-biofortified products, while cultivars bred for increased iron or zinc density are visually indistinguishable from other varieties. This has implications for labelling and pricing, as well as the potential for targeting particular populations 'at risk' from malnutrition-related illness, raising a different set of challenges with regard to impact assessment. The focus of this chapter is on efforts, centred in the International Rice Research Institute (IRRI), to biofortify rice with the trace minerals iron and zinc. Contestation around this research has been relatively restrained, mainly because the research has relied largely (but not exclusively) on 'conventional' plant breeding rather than more controversial transgenic technologies. A key claim made for iron- and zinc-dense varieties is that they offer a 'win–win' solution combining nutritional benefits with improved agronomic performance (realising higher yields, particularly in nutrient-deficient soils; Bouis 1996), making this a particularly interesting case from a contested agronomy perspective.

This chapter traces the history of research aimed at producing iron- and zinc-dense rice varieties. It highlights, at each stage, which dimensions were contested and which were not, and how this contestation (or lack of it) was linked to particular configurations of actors, disciplines and broader institutional factors. It explores how the problem to be addressed by the research was defined or 'framed' (Schön and Rein 1994) in ways that both reflected and reinforced particular sets of interdisciplinary relations. These dynamics are viewed through the lens of interdisciplinary relations and contests that emerged in each stage of the research. This analysis highlights how scale assumptions embedded in certain disciplines (or in particular approaches within disciplines) could be marshalled to tilt the interdisciplinary playing field, with implications for research directions and science practice. Furthermore, these dynamics 'at the interface' (Long 2001) between epistemic traditions unfolded within a broader institutional context that was itself in a state of perpetual transformation. A key contribution of this chapter is that it offers a cross-scale analysis of contested agronomy linking the micropolitics of interdisciplinary 'boundary work' (Gieryn 1999) with the broader power-knowledge relations that characterize these increasingly globalised research networks.

The pre-breeding study – establishing feasibility (1994–99)

This section outlines the series of events through which plant breeding for micronutrient density found its way onto the CGIAR research agenda. This was due, in large part, to a small network of like-minded people who championed the approach at a time when it was perceived by many within the CGIAR as unrealistic and somewhat eccentric. It focuses on particular moments when the biofortification research agenda was subtly reframed to bring in different constituencies, particularly the CGIAR plant breeders on whom the approach (as conceived by its promoters) depended.

In 1993, the International Food Policy Research Institute (IFPRI) received funding from the USAID Office of Nutrition to identify ways in which CGIAR 'might undertake to join other international and national organisations in the fight against micronutrient malnutrition' (Bouis 1995a: 11). While this idea initially received a lukewarm response from CGIAR scientists (mindful of the early QPM experience), a breakthrough came with the discovery of a network of scientists advocating a 'food systems approach' to the problem of micronutrient malnutrition (Combs et al 1996). This was envisaged as a holistic and 'inherently interdisciplinary' approach in which plant breeding research was integrated with research into micronutrient bioavailability[5] and food technology. The institutional home of this approach was the Cornell-based Federal Plant, Soil and Nutrition Laboratory (PSNL), which 'had, since the 1930s, been investigating linkages between minerals in soils and the nutrition of plants, animals and humans in the United States' (Bouis 1995a: 12).

At this time, Ross Welch of the PSNL introduced Howarth Bouis, based at IFPRI and the CGIAR's main advocate of biofortification research, to Robin Graham of the Waite Agricultural Research Institute at the University of Adelaide.[6] Graham was conducting research on crops bred for more efficient uptake of trace minerals such as iron and zinc from deficient soils (Bouis 1995a: 12–13). Graham's aim was to use this trait to improve wheat yields in zinc-deficient soils in Australia. Meanwhile, a research programme was under way to adapt Australian zinc-efficient varieties for the zinc-deficient soils in Turkey, with the aim of improving plant and human nutrition simultaneously (Cakmak

1996). It was estimated that 'Turkish wheat farmers would save $100 million annually in reduced seeding rates alone' (Cakmak 1996: 13).[7] Graham, Welch and Bouis envisioned a 'win–win situation' (Graham and Welch 1996: 15–16) in which crop yields would be enhanced 'without additional farmer inputs' alongside improved nutritional quality (Welch and Graham 2004: 356), through a strategy of 'tailoring the plant to fit the soil'. However, the implied synergies between plant and human nutrition benefits were still unproven at this stage (Bouis 1995b: 18).

In 1994, IFPRI hosted a workshop entitled 'Agricultural Strategies for Micronutrients', which led to the establishment of the CGIAR micronutrients project (1994–99) (Bouis et al 1999). The merits of various breeding strategies were explored and mechanisms regulating plant and human nutrition were discussed. In the published output a strategic simplification was made, which proved critical in convincing CGIAR plant breeders to participate. It was articulated as follows: 'The genetics of these traits is generally simple, making the task for breeders comparatively easy … the primary selection criterion is a simple and efficient one – the micronutrient content of the seed' (Graham and Welch 1996: 55). This problem redefinition spoke directly to the prevailing, genetics-led approach to crop research within the CGIAR by framing grain micronutrient content as an 'isolable problem' (Anderson et al 1991), which could be approached in the same way as other stress-tolerant traits. And so the 'food systems' framing was replaced by a familiar CGIAR narrative – the solution was 'in the seed' (Brooks 2010).

Meanwhile, a group of IRRI plant breeders led by Dharmawansa Senadhira were developing rice varieties for 'problem soils' characterised by salinity and mineral toxicity and deficiency. This group produced a cross called 'IR68144', an aromatic variety suited to 'cold elevated areas'. At this time, Senadhira became aware of the CGIAR micronutrients project, which prompted a shift to nutritional breeding objectives.[8] At the same time, the attention of his Filipino colleagues was drawn to a national campaign to combat iron-deficiency anaemia following the 'Ending Hidden Hunger' conference in Montreal in 1991 (Gregorio et al 2000: 382; see also Graham et al 1999). As a result, while IR68144 contained elevated levels of both iron and zinc, it was its identity as a high-iron cultivar that was emphasised. In 1999, an IRRI-convened conference, which brought together crop scientists and nutritionists to discuss strategies for 'improving human nutrition through agriculture', provided Sehandhira's team with an opportunity to showcase their recently discovered 'high-iron rice':

> A high-iron trait can be combined with high-yielding traits. This has already been demonstrated by the serendipitous discovery … of an aromatic variety – a cross between a high yielding variety (IR72) and a tall, traditional variety (Zawa Bonday) from India – from which IRRI identified an improved line (IR68144–3B-2-2-3[9]) with

> a high concentration of grain iron (about 21ppm[10] in brown rice). … yields are about 10% below those of IR72, but in partial compensation, maturity is earlier. This variety has good tolerance to soils deficient in minerals such as phosphorus, zinc and iron.
>
> (*Gregorio et al 2000: 383*)

While the 'serendipitous discovery' of IR68144 appeared to confirm the feasibility of rice biofortification, questions remained about its performance under different agro-ecological conditions. The question of genotype–environment interactions, however, would be dealt with through the usual process of varietal evaluation following multi-location trials, so these were put on hold. For the time being, the focus shifted to the nutrition parameters of bioavailability and bioefficacy (the extent to which adsorption of these nutrients effects a measurable change in human nutrition status) as representing 'the final unknown' (Brooks 2010). Bouis and Senadhira's team now looked to Angelita del Mundo, a nutritionist at the neighbouring Institute for Human Nutrition and Food at the University of Philippines, Los Baños, who had for many years advocated the incorporation of nutritional parameters into rice breeding programmes.[11] Del Mundo proposed a 'feeding trial' be conducted to test the bioefficacy of iron in IR68144; and proposed Catholic convents as an 'ideal' setting for such a study (Haas et al 2000: 442). Collaborators would include Jere Haas of the Division of Nutritional Sciences at Cornell and John Beard from the Department of Nutrition at Pennsylvania State University. Following this presentation, new funding was secured from the Asian Development Bank (ADB) for continued research on iron-biofortified rice – on the condition that the feeding trial formed an integral part of the programme.[12]

The feeding trial – focus on nutrition (2000–03)

This section focuses on the systematic nutrition study which, it was hoped, would convince the international nutrition and donor communities to support biofortification. The study that Del Mundo and her colleagues designed was an ambitious nine-month feeding trial which involved, as research subjects, more than 300 religious sisters in ten Catholic convents across Metro Manila. It was both a landmark study and a major logistical challenge which was extremely demanding of the small, close-knit inter-disciplinary team of nutritionists and plant breeders. This team, or 'research family' as they called themselves, displayed particular characteristics that shaped the study in ways that have tended to be overlooked during subsequent contestation.

With the prioritisation of the bioefficacy study, the emphasis of the project shifted to nutrition, using the 'high-iron rice' IR68144 as the material 'developed at the IRRI for experimental use' (Haas et al 2005: 2825). The feeding trial was a 'prospective, randomised, controlled, double blind, longitudinal (9 month) intervention trial involving 317 women. The study had two arms: low-iron rice and high-iron rice, which were the exclusive sources of rice consumed [by the research subjects] for nine months' (Haas et al 2005: 2824). In preparation for the feeding trial, crop scientists at IRRI conducted a series of experiments to measure the effects of production, milling and cooking of IR68144 in comparison with the proposed control. Thus far, the screening of varieties for iron content had been conducted on dehulled but unmilled 'brown' rice. However, in the Philippines (and elsewhere in the region) rice is usually consumed in its milled 'white' form. This was the first time that the research team had evaluated the effects of post-harvest processing (milling, rinsing, cooking) on grain iron content. They found that milling and rinsing had a far greater impact on the iron content of cooked white rice than previously assumed, to the extent that the differential between the 'high-iron' and 'low-iron' rice was reduced to a level that threatened the viability of the study:

> In effect, the differential between IR68144 and PSBRc28 [the original control] is largely based on milling and not genotype. … The differential may be achieved if a commercially produced rice … will be used opposite to IR68144 … treatments such as milling of IR68144 and washing of rice prior to cooking should be taken into consideration to maximize the differential.
>
> (*Gregorio et al 2003: Conclusions and recommendations*)

Adjustments had to be made in order to engineer the iron differential required for the study to go ahead, including the selection of a new control and the development of a milling strategy that involved under-milling IR68144 and over-milling the control. Since under-milled rice does not store well, supplies of the 'high-iron' rice had to be delivered to the participating convents on a fortnightly basis. These adjustments placed demands on the researchers, which they absorbed willingly. The location of the research in Catholic convents held particular significance for the Filipino 'research family', who were all of the Catholic faith. Del Mundo, in particular, 'had always dreamed of working with religious sisters' in her research work (Del Mundo 2003: 82). This convergence of science and religion[13] was also reflected in the convent leaders' decision to accommodate the research, once convinced that participation constituted a form of 'humanitarian service'.[14]

Questions remained, however, about how the 'high-iron' status of IR68144 might be sustained beyond the carefully controlled feeding trial. The elaborate logistics required to maintain the identity of the 'high-iron' material was just a taste of the challenges to come in maintaining its integrity as a commercial variety with distinct (yet invisible) characteristics. Consideration of the implications for traceability, pricing and attributable nutritional impact in 'real-world' conditions was shelved. The seeds of future contestation were sown with the claim that such a partial and contingent success would represent 'proof of concept' (an ambiguous claim in itself); particularly since the IR68144 materials had, by then, been submitted for varietal testing, with the expectation that the conclusion of the feeding trial would coincide with the launch of the Philippines' first high-iron rice variety.

During routine varietal testing, the agronomic performance of IR68144 did not match expectations, so it was released with the more cautious certification of a 'special variety' and named MS13 (Padolina et al 2003: 11; Corpuz-Arocena et al 2004). Meanwhile, MS13 seeds were transferred to the Philippine Rice Research Institute (PhilRice) for seed multiplication and varietal promotion. It was at this point that agronomists began investigating the variability of the 'high-iron' character of MS13/IR68144 more closely, discovering significant variation in grain iron content across contrasting agro-ecological conditions and between seasons.[15] It was in the context of these questions about the relative contribution of the genotype (G) and environmental (E) factors that some agronomists began to question the wisdom of privileging a genetic-led approach to biofortification. Surely these findings suggested that environmental testing might play a useful role in informing breeding strategies (cf. Simmonds 1991)? As one scientist explained: ' … they identify genotypes first, without understanding the cultural practices that will optimise the expression of iron … If they did an agronomic study first, then the true breeding parents would have been used'.[16]

Globalising biofortification: negotiating programme-wide breeding targets (2004–06)

In 2003, funding was secured for a joint proposal from CIAT and IFPRI for a biofortification 'Challenge Program' called HarvestPlus (CIAT and IFPRI 2002). This included funds from a new donor, the Bill & Melinda Gates Foundation (BMGF). This section charts the transformation of the ADB-funded regional rice biofortification initiative into the rice crop component of this new global pro- gramme. In the process, new actors congregated around a vision of a series of 'gold standard'[17] biofortified lines, developed according to a system-wide framework of breeding targets. Meanwhile, the outputs of earlier research – including the mixed performance of IR68144 – presented dilemmas for a new team of research managers poised to 'scale up' rice biofortification research.

The results of the feeding trial were published in 2005, with the conclusion that 'consumption of biofortified rice, without any other changes in diet, is efficacious in improving iron stores of women with iron-poor diets in the developing world' (Haas et al 2005: 2823). This was an important milestone, which coincided with a change in personnel involved in rice biofortification research at IRRI.[18] A 'research family' rooted in the Philippine context gave way to an internationally focused network of researchers now tasked with conducting iron-biofortified rice research under HarvestPlus.[19] Distancing themselves from IR68144/MS13, they asserted that, while as a variety it was far from 'gold standard', the feeding trial had provided the necessary 'proof of concept' to justify investment in further research.

But what had been proven? As discussed in the previous section, problems had emerged in the run-up to the feeding trial, and later in varietal testing, that cast doubts on the wisdom of a genetics-led approach to biofortification. While the former had highlighted the importance of post-harvest practices in determining grain iron content (Gregorio et al 2003), the latter suggested that environmental rather than genetic factors might be more significant. By this time, however, the HarvestPlus Program, which institutionalised a genetics-led strategy, had been endorsed by the newly established CGIAR Science Council. The Science Council was committed to a return to model of 'high-impact' public goods research (Science Council 2006), which within the CGIAR was equated with genetics-led research (Brooks 2011a). Furthermore, this equation linking 'impact at scale' with a genetics-led approach had been key to securing the support of the BMGF for biofortification at a time when the CGIAR's traditional donors were still cautious.[20] The next step would therefore be to resume the search for rice germplasm with higher grain iron content in accordance with centralised, programme-wide targets.[21] Having streamlined the problem definition thus, it was not long before IRRI scientists were debating whether transgenic methods might be a more efficient way to achieve these targets than conventional plant breeding.[22,23]

Those now tasked with steering rice biofortification research under HarvestPlus drew selectively from the previous research phase, claiming 'proof of concept' for the efficacy of iron-rice biofortification (as well as, even more questionably, a 'bioavailability number' for iron in rice-based diets[24]). At the same time, the question of technical feasibility with respect to biofortification through conventional plant breeding was being reopened – the key question now was whether HarvestPlus nutrient targets necessitated a transgenic approach. As a result, research at IRRI on iron-biofortified rice began to follow two parallel paths – based on the use of first, conventional plant breeding and second, transgenic techniques. This development suggested that the choice facing decision-makers was between the objective merits of two technologies; obscuring the fact that the critical decision had already been made. In both cases, research would follow a genetic-led strategy focusing on centralised targets based on calculations of 'impact' in relation to generic 'populations at risk'. This shared understanding of the choices ahead enabled plant geneticists to define the parameters of engagement with other disciplines, including human nutrition.[25]

Nowhere was this more apparent than in an encounter between plant breeders and nutritionists over the setting of programme-wide breeding targets. With HarvestPlus framed as a strategy in which 'agriculture would be an instrument for human health' (Graham 2002), these targets were to be set at a level that would achieve a significant health impact. However, it soon became clear that such targets would be difficult to achieve within the first phase of the programme. Plant breeders proposed they work towards 'intermediate targets', as is consistent with the common practice of 'breeding up', and releasing a series of improved products over time, 'like Honda cars'.[26] But to the nutritionists, this made no sense: 'you either have the level for biological impact or you don't.'[27] The plant breeders won the argument and intermediate targets were adopted. For the nutritionists, this was a turning point which demonstrated that HarvestPlus remained, first and foremost, a crop improvement programme. As one nutritionist remarked; 'whenever nutrition throws up a challenge, [plant breeders] move the goalposts!'[28]

With the changes accompanying the transition from the ADB-funded project to the global HarvestPlus programme, including the interdisciplinary contestation outlined above, a key lesson from the IR68144/MS13 experience failed to attract attention. When MS13 was released in 2003, members of the 'research family' anticipated a positive response from farmers and consumers, mindful of governmental initiatives to support fortification of staple foods with essential nutrients.[29] However, the release coincided with the launch of a major subsidy programme for hybrid rice producers in the year leading up to the 'International Year of Rice' (PhilRice 2006). Thus the high-iron rice project was but a short chapter in a more complex story of science, policy and politics in the Philippines, in which a narrative of rice self-sufficiency remains as emotive and powerful as it was at the height of the Green Revolution (Brooks 2011b). When asked what was the most important lesson to be drawn from the experience of IR68144/MS13, one participant in the varietal assessment process put it succinctly: 'national priorities matter'.[30]

The shift to zinc: genetic or agronomic biofortification? (2007–10)

By 2007 another series of shifts was under way. The HarvestPlus team had succeeded in securing funding for a second phase. The Challenge Program structure was being questioned during discussions then taking place in the CGIAR around a series of 'mega-programmes'. Meanwhile, those steering rice biofortification research at IRRI recognised that the prospects of meeting HarvestPlus targets using conventional plant breeding alone were increasingly unlikely. Nevertheless, during the first phase of HarvestPlus, plant breeders at IRRI had been screening known rice cultivars for both iron and zinc grain content. A key factor was the exact location of these nutri- ents within the grain. While a substantial amount of grain iron content is concentrated in the aleurone layer, which is removed in the milling process (so that levels dropped below target levels in white rice – as had been discovered in preparations for the feeding trials), milling had a relatively small effect on grain zinc content (Johnson-Beebout et al 2010). The decision was taken, therefore, to proceed with conventional plant breeding for zinc and transgenic research with respect to iron.

The shift to zinc created new spaces for the development of a different culture of interdisciplinary enquiry at IRRI. This collaboration was prompted by plant breeders' and soil scientists' shared sense of curiosity and puzzlement that neither had been able, from their own disciplinary perspective, to explain observed G x E interaction in grain zinc concentration. Encouraged by managerial changes supportive of interdisciplinary collaboration, a new cohort of young scientists has begun to explore new avenues of research. Importantly, this transformation has taken place, not according to an a priori plan, but through an evolutionary process that has followed the formation of lateral relationships between scientists, through serendipitous events, informal connections and friendship. As one scientist commented; 'it helped that we are all women about the same age, and we communicate more easily than the larger group which included mostly men, and mostly more senior scientists'.[31]

From late 2006 onwards, this group continued to meet as a 'cross-disciplinary group of zinc researchers within IRRI' to discuss their work, while continuing to design their own experiments in the normal way. Soil experiments were designed around a range of variables but utilised only one or two genotypes and were therefore 'only moderately interesting to breeders'. Similarly, breeders carried out multi-location trials from which they collected data via 'routine soil tests', which was of little use to soil scientists attempting to interpret the G x E results as the data did not relate to zinc availability. As one scientist explained, 'it took us a long time to realise how differently we understood G x E effects in different disciplines'.[32] A turning point came when funding was secured to recruit a post-doctoral researcher for the project and, instead of an additional plant breeder or agronomist, a plant physiologist was appointed. This individual proved to be the vital link in the interdisciplinary web, able to explain to plant breeders and soil chemists why specific rice varieties perform differently in different environments. These interdisciplinary discussions, enabled as much by personal relationships as any organisational plan, led to the design of a specific set of experiments to answer each other's questions. By early 2011, the group were planning 'plant breeding experiments in strategic locations' representing varying zinc availability, thus enabling the simultaneous collection of plant physiology and soil-related data.

In parallel with these developments at IRRI, however, a new global project has been launched under the auspices of HarvestPlus, based on a different type of agronomy optimising the use of zinc fertiliser technology. Tellingly, this project incorporates scalability assumptions comparable with those of genetics-led biofortification under the first phase of HarvestPlus. In this case, a global mining industry in search of new ways to demonstrate corporate social responsibility and 'mineral stewardship' by promoting zinc as a product that is uniquely 'natural, essential, durable and recyclable' (Green et al 2010) is emerging as a powerful new actor. Initiatives to date have included a high-profile 'Zinc Saves Kids' supplementation campaign (in partnership with UNICEF[33]), and now the industry-sponsored 'HarvestPlus Global Zinc Fertilizer Project'.[34] The latter involves widespread application of zinc fertiliser as a 'short-term' solution to serve as a stop-gap until 'genetic biofortification' (still the 'optimum' strategy) produces its long-awaited results:

> Application of Zn fertilizers or Zn-enriched NPK fertilizers (e.g. argronomic biofortification) offers a rapid solution to the problem, and represents [a] useful complementary approach to on-going breeding programs.
>
> (*Cakmak 2008: 1*)

This view of zinc fertiliser as a 'silver bullet' is contested by agronomists working in the field. The initial success stories of zinc fertiliser-induced biofortification involved only wheat (Cakmak et al 2010; Erenoglu et al 2010). These studies demonstrated the effectiveness of both soil and foliar applications of zinc in increasing grain zinc content, in at least some Zn-deficient environments. However, rice is different from wheat in two important respects. First, it is grown in flooded soils and 'flooding the soil changes everything' (Johnson-Beebout et al 2010). In particular, soil-applied zinc fertiliser sometimes becomes rapidly unavailable to plants after the soil has been flooded (Johnson-Beebout et al 2009). Second, zinc applied on the foliage is not as easily moved into the grain in rice as it is in wheat, due to fundamental physiological differences between the two species (Jiang et al 2007; Stomph et al 2009); although there is still debate about the level of genetic variation within rice varieties for this trait. Wissuwa et al (2008) have therefore cautioned against the use of zinc fertiliser as a generic solution, highlighting results showing 'native soil Zn status' as the dominant factor determining grain Zn concentrations 'followed by genotype and fertilizer'. They argue that it is 'not possible to simply compensate for low soil Zn availability by fertilizer applications' (Wissuwa et al 2008: 37). Plant breeders, however, have contested this, arguing that the genotypes used in the study did not include sufficient genetic variability to support such a conclusion.

Thus biofortification remains a site of contested agronomy. At IRRI, contestation is confined to technical feasibility questions debated among crop scientists. Meanwhile, nutrition studies are conducted elsewhere, with research partners in Bangladesh, with whom, under current organisational arrangements, IRRI crop scientists have little interaction. Similarly, wider issues of effectiveness and appropriateness, such as whether poorer farmers will ultimately be able to afford zinc fertilisers, are 'dealt with' elsewhere within an increasingly dispersed global network.

Conclusions

This chapter takes biofortification research as a case study in contested agronomy, in which a body of knowledge about complex interactions between genotypes, soils, human bodies and populations has evolved over time, in ways that have both reflected and reinforced particular sets of interdisciplinary and interinstitutional relations. In the process, certain types of knowledge have presided over others, with the result that some dimensions of this complex, multidimensional project have been contested, while others have not. Research in each phase has been both groundbreaking and partial – something is always left out – with the consequences of blind spots inherent in one phase being carried over to the next. In this context, biofortification has been an arena of continual contestation, nourished by a succession of 'new paradigms', inflated claims and counterclaims, and never quite resolved.

These dynamics have been examined through the lens of interdisciplinary relations and contests that have characterised different stages of the research. Specifically, the chapter has traced efforts centred at IRRI to develop rice cultivars enriched with the trace minerals iron and zinc. This analysis has shown that the 'software' of interdisciplinary collaboration – built on collegial relations that are difficult to cultivate at a distance – is as important as the hardware that can be drawn on an organisation chart. In particular, a crucial element of fruitful interdisciplinary exchange has been the formation of lateral connections between early career scientists (not yet constrained by imperatives to simplify results and secure future funding) – who have been motivated to learn more about the function of each others' disciplines. Nevertheless, these have tended to be islands of beneficial interdisciplinary contestation and learning that have emerged at particular moments, through serendipitous connections, informal relations and friendship, which have not, thus far, been institutionalised. As a result, interdisciplinary collaboration throughout 15 years of biofortifciation research at IRRI has been variable, inconsistent and partial; and opportunities for institutional learning have been elusive. The globalisation of biofortification research is predicated on the principle of interdisciplinary collaborative research. In practice, however, the research is increasingly compartmentalised, with specialised components of research dispersed throughout global, heterogeneous networks of institutions and individuals. This effectively closes spaces for contestation, often when and where it is most needed. This chapter has highlighted the inherent challenges in widening (rather than narrowing, as is the current trend) interdisciplinary exchange to incorporate broader issues – political as well as technical – that will ultimately have the greatest influence on the effectiveness of biofortification as a real-world intervention. With zinc-biofortified rice now identified as a 'product line' within the Global Rice Science Partnership (GRiSP, formerly the Rice Crop 'Mega program') (IRRI et al 2010), this would be an appropriate time to review the lessons highlighted by this chapter and consider their implications for research design and practice.

Notes

1. In Chapter 1 of this volume, agronomy is defined as 'the application of plant and soil science to crop production'; however, in this chapter we use the term agronomy as understood at IRRI, where there is a clear organisational division between the constituent activities (and related disciplines) of crop improvement (genetics), crop management (agronomy), and grain quality (cereal chemistry and post-harvest/agricultural engineering) [interviews, Institute of Human Nutrition and Food (IHNF) and IRRI, June 2006; www.harvestplus.org].
2. For example, a recent meta-analysis of community-based studies of the nutritional impact of QPM generated results that were encouraging, but not conclusive (Gunaratna et al 2009).
3. Interview, HarvestPlus, 31 January 2006.
4. Interview, former CGIAR director, 20 January 2006.
5. The term 'bioavailability' refers to the proportion of nutrient the body can extract from food items and make available for utilisation.
6. Interview, Cornell, 19 January 2006.
7. 'The potential economic returns on research aimed at helping Turkish farmers on zinc- deficient lands reduce their seeding rate are tremendous', says Braun [of CIMMYT's Wheat Programme]. 'A reduction of 80 kg/ha could save about 400,000 tons of seed a year, with an estimated value of US$80 million' (CIMMYT 1995).
8. Interview, IRRI scientist, 9 June 2006.
9. The full name of the variety, normally abbreviated to IR68144.
10. Parts per million (sometimes expressed as μg/g).
11. Interview, IHNF, 26 May 2006.
12. Interview, HarvestPlus, 27 January 2006.
13. Interview, IRRI scientist, 16 December 2006.
14. Discussions with 'family members' en route to visit participating convents, 21 December 2006.
15. Interview, PhilRice, 7 June 2006.
16. Interview, PhilRice, 30 May 2006, original emphasis.
17. Interview, IFPRI, 17 January 2006.
18. Interviews, IHNF and IRRI, June 2006.
19. www.harvestplus.org
20. Interview, BMGF, 30 November 2005.
21. Interviews, HarvestPlus, January 2006.
22. Interviews, IRRI, November and December 2006.
23. This view solidified following publication of research showing that the bioavailability of iron in ferritin, the proposed source material, compared favourably with ferrous sulphate, a common

fortificant (Davila-Hicks et al 2004).

24. Interview, IRRI, 2 June 2006.
25. Interview, HarvestPlus, 31 January 2006.
26. Interview, IRRI scientist, 30 May 2006.
27. Interview, nutritionist, HarvestPlus, 16 February 2006.
28. Ibid.
29. Food Fortification Law (2000).
30. Interview, Rice Variety Improvement Group member, PhilRice campus, Nueva Ecija, 17 January 2007.
31. Ibid.
32. Interview, IRRI scientist, 25 November 2010.
33. www.zincsaveskids.org
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CHAPTER 5

Rethinking Regulation

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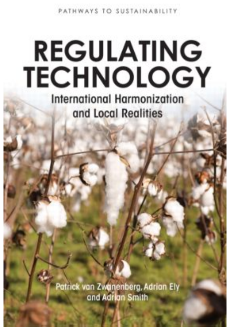

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Introduction

We chose to study the harmonizing regulation and use of transgenic cotton seeds and antibiotic medicines, as opposed to other technological artefacts, for several reasons. Both types of seed and drug are in global circulation and are used by poorer people in both project locations, and both are important technologies with the potential to significantly impact on welfare and sustainability in various ways. They are both associated with regulatory pressures at a global level that articulate particular norms and seek their implementation across diverse contexts. Such norms frame the room for manoeuvre of national governments, who have to reform or even create regulatory apparatus, and who have also to confront domestic political issues and diverse contexts of use. Such multi- level regulatory combinations generate different opportunities and concerns in different locations. This presents something of a challenge for purposeful regulatory governance.

Other technologies could have been chosen but we used these two technologies as test-beds for developing a methodology that explores how the technology-related norms sought by internationally harmonizing regulations compare, contrast and overlap with actual socio-technical practices amongst poorer users in places where the technologies are widely used. Our approach could be used in any situation where there is an attempt to project distant norms onto local practices. For example, many environmental agreements involve the articulation, at a global level, of desired technology-related norms, as do some transnational policy responses to global climate change such as low carbon technology transfer. Technology-related norms are promulgated at international level by both public and private sectors in a wide range of areas such as food, energy, transport and telecommunications. Emerging technologies associated, for example, with nano-materials or synthetic biology are likely to involve the creation of global regulatory norms over their production and use.

Our empirical work summarized in the core chapters of this book has revealed repeated limits to the local governability of transgenic cotton seed and antibiotic technologies. This is especially so in terms of providing assurances for poorer users, but also for other actors who use and produce the technologies, as well as for more diffuse public good issues. This concluding chapter begins with a brief summary of our arguments as to why we found a lack of evidence of 'pro-poor' regulation, and of other limits to the governability of those artefacts. We argue that such limits are important because they have a bearing on the development pathways possible with those technologies. We substantiate that argument before turning to consider the implications for rethinking regulation in ways that are more inclusive of poorer peoples' aspirations and concerns over the diffusion of technological benefits and risks, and that can encourage pathways of socio- technical change that are more socially just and environmentally sustainable.

Regulatory Reach

Chapter 5 illustrated how regulation fails to assure poorer farmers in Chaco, Hubei and Shandong that the seed they use is of good quality and certain identity, that seed firms can control the commercialization of their own cotton varieties, or that international norms for managing access, managing resistance and ensuring prior biosafety approval can be met. Chapter 7 illustrated how regulation fails to assure patients in certain parts of Hubei and Shandong that they are not prescribed overly expensive and unnecessary antibiotics, or that international norms for managing microbial resistance are in place.

Some of these limits would be attributed, conventionally, to a combination of insufficient implementation capacity and foot-dragging on the part of the Chinese and Argentine governments over the implementation of international norms. Prescriptions for improving regulation under this view involve international pressure on the governments to conform, and capacity-building programmes for their regulatory apparatus. It is indeed the case that national governments have constructed their own interpretations of international technological norms, in light of their domestic priorities; that implementation capacity is weak in many of our cases; and that this, coupled with a lack of inclination on those (nominally) subject to regulation to comply with regulatory requirements, impedes the realization of sought for technological norms. Yet our multi-level backward-mapping approach has also revealed that many of the limits to the governability of seed and drug technologies that we have described are beyond the scope of 'capacity-building', resource improvements in regulation or legalistic/administrative reform alone.

We see also that regulatory 'framings' of what constitutes appropriate access and managed risk are blind to some of the critical socio-economic conditions and processes on the ground that determine the actual use of the technologies amongst poorer farmers and patients. The kinds of risk and access problems faced by poorer farmers and patients contrast, often markedly, with the ways in which international regulatory mandates understand, or frame – and national and local regulators reframe – those issues, with corresponding implications for the kinds of regulatory intervention that are put into practice. Regulators see the world in ways that are partial and selective, even in relation to their mandates. The cases confirm how important it is to disaggregate regulatory levels.

International technological norms for both artefacts are primarily concerned with promoting models of risk regulation and rules concerning access that are minimally disruptive of trade, that facilitate the commercial innovation and diffusion of the technologies, and that enable the capture of rents from investments by innovative firms. These international norms, a product of multilateral negotiations between states and international lobbying by firms and other non-state actors, largely assume that technology producers and users should operate in formal, transparent markets, and thus invariably privilege producers/users in these contexts. International secretariats seek to ensure the adequate transposition of those norms into national legal frameworks through capacity-building programmes and by preparing technical documents and guidelines.

In our case study countries, the national level has reformed its regulatory frameworks in response to those norms primarily in order to comply with integration into globalizing markets. In both the seeds and drugs cases, China's reformulation of national regulations has been led by the central government, which has an interest in the harmonization of general purpose regulations as a means of further inclusion in the multilateral trading system, although at the same time it has sought to do this in ways that protect and promote its domestic seed and drugs industries, and that promote access and manage risk. In the Argentinean seeds case, central government was not interested in harmonization per se. Rather, it was encouraged to do so by key agri-business constituents who needed a regulatory framework that would provide assurances to importing markets overseas, and thus allow them to export whilst simultaneously adapting new technologies to their needs. In the drugs case, reform of national regulations was driven by the Executive as part of its broader liberalization programme, and by multilateral trade obligations and bilateral pressure, although modulated by concerns about protecting the domestic generics drug industry. In other words, there is a national level of regulatory framing that looks to international requirements and seeks to satisfy them in ways that accord with major interests in the national political economy. Indeed, national regulatory purposes are in none of the cases simply a mirror image of those international norms; rather, those international norms are reinterpreted and reshaped, partly as a result of the ways in which powerful domestic interests have sought advantage, and have subsequently influenced national regulatory frameworks, and partly as a result of how political elites have interpreted the public good in light of their domestic realities and constituencies. Poorer farmers' and patients' circumstances and interests have been peripheral to these responses, although in both settings drug rules that are not subject to harmonizing norms have been introduced, alongside elements of broader health policy, in order to counteract the effects of liberalization on access to drugs for poorer patients.

At a local level, regulators in both settings are constrained in most cases by resource limitations but also by their mandates, which reflect national framings. Thus in the seeds cases, local Argentinean regulators only attempt to control seed quality in formal commercial markets, as their mandates require, and it is only large farmers who benefit from those assurances. In Hubei and Shandong, regulators focus on licensing activities, rather than more directly on control of artefact quality; a reflection both of their mandates and the need at a local level to raise revenue through licence payments. They consequently struggle to assure farmers of quality seeds. In the Chinese drugs cases, the focus on checking supply chains in order to reduce low quality products is improving the situation for individual patients, and in both settings access issues have been addressed through price controls and compulsory generic prescription, and indeed via broader health policy (free provision in Argentina and health insurance in China). Nevertheless, in relation to rational antibiotic use practices, local regulators in both Argentina and China have almost no formal mandate, and the sustained efficacy of these drugs is severely threatened.

To various degrees, depending on the case, the circumstances and aspirations of poorer users of those artefacts fall at least partially outside of national and local framings. We see this far more so in the seeds cases as compared to the drugs cases. Small cotton farmers' risk and access problems in Chaco differ entirely from those that regulators focus on, and arise within systems that regulation fails to appreciate. In Hubei and Shandong, farmers' main risk problems – lack of reliable information and reliable seed supply systems – do not coincide directly with local regulatory purposes, even if local regulators are aware of these challenges. By contrast, in the drugs cases, access issues for poorer patients were addressed within regulatory framings. However, in terms of antibiotic risk, the incentive structures shaping the ways in which doctors in both settings provide antibiotics, and in Hubei and Shandong poorer patients' own understandings of antibiotics and their livelihood circumstances, lie outside of regulatory framings of drug risk.

These broad divergences in the seeds cases, and the somewhat more limited contrasts in the drugs cases, arise largely because of the particular institutionally positioned and interest-based perspectives and actions of those actors responsible for (and in some cases subject to) regulation. In particular, regulatory framings reflect the ways in which state priorities in health and agricultural policy, and the relative power and voice of different producer groups, have managed to work round the constraints posed by international norms, but with little influence on that process from the perspective of poorer users. This is not just about competing interests per se, but the ways in which interests, institutional assumptions, and experience combine to frame how actors see and understand the world. Not only are there different ideas and priorities about, and political conflicts over, how to regulate. The socio-technical systems in question are themselves understood in partial and selective ways by regulators and other actors, and assumptions are effectively made about those systems that often fail to capture what is really happening in practice.

In sum, we see a lack of regulatory reach, in both the senses outlined at the beginning of this book. In the first, and more conventional sense, the resources of regulators are, in most of our cases, not sufficient to bring technological practices into line with the rules set in their formal mandates. At the same time, however, we see that local social and political realities and contexts undermine aspirations for the implementation of those technological norms, regardless of administrative capacity, because those contexts remain only partially recognized by regulatory frameworks. Moreover, those differing contexts have not prompted the reopening of questions of whether regulations have sufficient scope and flexibility to work with the grain of local conditions.

From a decentred or post-regulatory state perspective, none of what we have shown empirically is of particular surprise. Issues or problems meriting regulation are the product of multiple interactions, some of which are understood poorly. Knowledge is fragmented and dispersed, so that issues and problems are only partially and selectively understood across different groups of actors. What we have been able to do, with an analytical focus on framing, and a backward- mapping methodology, is detail some of the ways in which regulatory issues – the objects of regulation and the problems deemed relevant – are appreciated in divergent ways. A focus just on resource/skills capacity-building, or simply on divergent national interests in the face of an assumed, commonly understood problem, would not capture this underlying reason for both the (non) implementation of internationally and nationally refracted regulatory norms, and the limits to 'pro-poor' regulatory assurances.

Why, we might ask, do our findings about the limits of technological governance from these cases matter? Our argument is that regulatory framings and, importantly, the associated problems of regulatory reach, have a bearing upon the development pathways possible with these technologies.

Pathways

Across all four cases, the ways in which regulatory mandates and practices have emerged and have been reformed since 1990 are in large part a reflection of dominant or desired pathways of socio-technical change in each national jurisdiction; those supported by powerful domestic interests. They are not necessarily a reflection of the ways in which international norms assume that technological pathways ought to unfold, although international regulations have some significant implications for what national governments can do now and into the future. At the same time, national regulations and practices have played at least a partial role in reinforcing prevailing or desired pathways (and inhibiting others). Importantly, however, in both cases and settings, albeit to different extents and in different ways, technologies and the social practices through which they are produced and used are also evolving in ways that are not sought by regulatory norms.

Thus, in the seeds cases we see that in Argentina regulations have accompanied and reinforced structural changes in seed supply that are constraining diversity and fostering a transgenic-based, commercial agricultural pathway based on technological solutions supplied by global life science firms (e.g. the demise of the National Institute of Agricultural Technology (INTA) as cotton seed breeder, and the emergence of a monopoly innovator in the form of Monsanto). This is a much broader process, but one that has itself shaped regulatory frameworks and practices, and which regulations subsequently contribute towards. Therefore, the initial development and subsequent form of intellectual property and biosafety regulations were largely a response to the regulatory preferences and interests of key agri-food businesses, especially transnational seed firms, but also those domestic seed firms and other domestic agricultural actors whose interests and preferences, in turn, had been shaped by international agricultural political economy. Once established, intellectual property regulations in Argentina, at least in principle, reinforce formal market-based processes of innovation, distribution and use and aim to hinder semi-formal or informal seed breeding, multiplication and delivery systems. Intellectual property regulations also reinforce the dominant role of global life science firms because of their asymmetric nature: The handful of international firms with capabilities in transgenics are able legally to make alterations to conventional seed varieties developed by local seed firms or public sector institutions (which remain without those capabilities) and then market those varieties. But the same process is not permitted in the reverse direction. INTA or domestic seed firms cannot use transgenic varieties for further breeding.

Biosafety frameworks in Argentina also have the effect of promoting a transgenic-based, commercial agricultural pathway of socio-technical change because of the criteria by which they permit and do not permit seed commercialization. Biosafety controls allow seed firms to introduce those crop/ trait varieties largely on the grounds of what makes private commercial sense (the regulatory hurdles are concerned only with physical risk and export market availability). Seedfirms' researchanddevelopment(R&D) andcommercialization decisions are aimed at the needs of large farmers who are the only customers of those seed firms. Regulatory frameworks do nothing to try and shift innovation in directions that are (also) appropriate to small farmers' production constraints and needs. In so far as transgenic seed innovations are useful for smaller farmers this is only because their production constraints and needs and those of larger farmers have happened to coincide, at least in part. The tendency for Argentinean regulations to reinforce a singular pathway of agricultural seed innovation and use is not entirely monolithic. Biosafety regulations are sufficiently flexible that on occasion they have been used to support domestic seed firms' entrance into the transgenic seed market (i.e. participate in the dominant pathway), whilst intellectual property frameworks have permitted large commercial farmers to capture most of the benefits from the seed technologies, such that the rationale for international seed firms to continue local R&D is weakened.

In the Chinese seeds case, regulations have accompanied and reinforced structural changes in seed supply that are fostering a pathway of change in which domestic private and public sector capabilities in transgenic seeds are coming to dominate, and which provides greater diversity in transgenic seeds (perhaps more suited to small farmers' production contexts) than within the Argentinean case. As we noted in Chapter 4, the Chinese government constructed its domestic regulatory regime for agricultural biotechnology in response to both its own domestic industrial and agricultural priorities as well as seeking to satisfy international technological norms in order to gain access to international markets. Both intellectual property and biosafety regulations have purportedly been used to support domestic seed firms, at the expense of overseas companies; a partially enforced intellectual property regime has permitted multiple seed firms to use Bt constructs in the production of their own varieties, which has benefited farmers.

A key point to raise here is that in both seeds cases it is not just harmonizing regulatory policy that reflects, and at the same time supports, particular socio- technical pathways of change. Broader agricultural innovation policy (and indeed agricultural policy more generally) fosters those pathways, whether deliberately or otherwise. As we highlighted at the beginning of this book, regulation is usefully defined as 'attempts by states to shape the broader governance of technology in order to promote the public interest'. This is not solely about rule making for established technology products and processes, but extends to broader aspects of innovation processes, although it is the former activities that are subject to harmonization processes. Thus, in China policy associated with agriculture and innovation more generally, as well as rules for biosafety and intellectual property, has intentionally tried to foster a domestic capability-based and intensive, smallholder-based, productivity-enhancing pathway of socio- technological change in the seed sector. In Argentina, on the other hand, a far more laissez faire approach exists. Neither 'back-end' regulation, nor agricultural innovation policy more generally, has sought to deliberately foster particular socio-technical practices. Instead, regulation, defined broadly, has largely deferred to the norms implicit in both harmonizing technological regulations and international agricultural political economy. This is because the aspirations for particular pathways of socio-technical change implicit in those norms are to a large extent shared by domestic agro-business elites.

Importantly, however, even though transgenic seed regulation in both settings has the effect of supporting dominant pathways (and of hindering others), in practice local pathways of change are diverging from those that regulation reflects and encourages. In Chaco, poorer farmers are left dependent upon co-operatives and provincial government hand-outs with little choice over their seed: an informal seed production and delivery system that the formal regulatory system cannot inhibit produces its own parallel trajectory of socio- technical change in which poor quality seeds of uncertain identity circulate, grown in contexts in which aspirations about resistance management and prior approval do not necessarily hold. In Hubei and Shandong, rapid liberalization of the seed sector, and the fact that seed firms are able to operate outside of strict regulatory norms, results in pathways of socio-technical change in which 'informal' seed production delivers the Bt gene in a broad range of germplasm backgrounds, raising questions for resistance management and seed quality more generally. Here, farmers struggle to identify reliable seeds, and use the resources available to manage the risks of low yields – information from formal and informal sources, the use of specific agricultural practices or reliance on personal relationships with suppliers. These unintended, often parallel, evolving pathways of socio-technical-ecological change are not necessarily desirable from poorer peoples' perspectives but are ways in which they can cope within their contexts of use. They may sometimes offer poorer farmers options that are unavailable in the formal, regulated systems sought under national and international norms, but they also present their own risks to poorer peoples' livelihoods, and to broader public goods. Local divergent parallel pathways of socio-technical change may also pose threats to the dominant pathways. For example, patterns of seed production and use that fall outside of biosafety controls may threaten the credibility of formal, regulated production, if, for instance, export markets suddenly close as a consequence of an inability to segregate approved and unapproved crops. Transgenic seed regulation, as currently designed, cannot provide clear boundaries within which technological pathways will develop.

The drugs cases are rather different to the seeds cases because regulation, and broader policy in this domain, has managed to partially constrain the emergence of pathways of socio-technical change that diverge from those sought by national norms. In the drugs cases, international technology norms on intellectual property in particular, and to a lesser extent safety, have accompanied the attempt, globally, on the part of the innovative drug industry, to expand into the markets of the South and undermine the emergence of powerful generics drug firms outside of North America, Japan and Europe. That pathway is highly contested globally, and has faced resistance in both our settings, largely because both China and Argentina have important domestic drugs industries. In Argentina, the implementation of Trade Related Aspects of Intellectual Property Rights (TRIPS) may, in the long term, encourage a pathway towards oligopolistic drug manufacture (and higher drugs prices), dominated by international drugs firms. Again, broader policy measures (the removal of import barriers, deregulation of the drugs markets) reinforce that pathway of change. Yet, thus far there is little effect on the domestic sector as the new intellectual property rules have had little effect. Moreover, patent law contains many of the flexibilities allowed for in TRIPS, and at present, 'informal' production of pharmaceuticals (in the sense of production occurring beyond international intellectual property norms) is supported by national regulatory institutions which sanction the quality and safety of 'similar' drugs even if their approval is not consistent with patent law. It is unclear whether regulatory changes in intellectual property alone will shift the prevailing pathway of a dominant domestic drug industry based on the copy of medicines produced elsewhere. In China, the implementation of TRIPS is fostering a pathway of change in which both the international drugs firms will have a larger domestic presence and the domestic drug industry will be consolidated, upgraded and will need to compete both nationally and globally with the existing, largely US- and European-based, firms. Broader innovation policy in China again reinforces those shifts, and the country's various health reforms provides a growing market for such producers.

Liberalization in the drug supply sector has been accompanied by a narrowing of drug access, mainly a result of increasing poverty and/or diminishing publicly funded health provision. Regulatory responses have taken the form of price controls, and essential drugs lists in both settings, but also broader health policy innovations that seek to subsidize or socialize the costs of drug provision – the introduction of insurance schemes in China and the provision of free medicines at primary health care levels in Argentina. Therefore, unlike in the seeds case, we have not seen the emergence of parallel pathways of change in which poorer patients are forced to seek and obtain drugs produced and exchanged outside of the formal drug production and supply system. It is not regulation, on its own, that has inhibited those parallel pathways, and helped assure pro-poor outcomes (in terms of providing low cost, quality, generic medicines), but rather broader health policy. However, in relation to antibiotic use, we do see that local practices diverge from the practices sought under international norms. We see, therefore, in the drugs case, how certain (non harmonizing) regulatory innovations and broader health policy have worked in tandem in order to address issues of access for poorer patients. This suggests that regulations need to be rethought in relation to broader agricultural and health policies, and all attuned to local circumstances, in order to generate more favourable pathways for poorer users.

Rethinking Regulation

We sought, across the case studies, to identify any informal 'regulatory' strategies that poorer users themselves had deployed in order to assure themselves of technological benefits and guard against risks. Farmers in Hubei and Shandong adopted a variety of strategies in order to insure against substandard seeds. These included purchasing mixes of seed in order to spread risk, cautious experimentation with limited proportions of new seed, and reliance on trusted sources and advice. In Chaco, by contrast, small farmers were more fatalistic about their dependence on the co-operatives and local government for seed provision, and there was less evidence of any informal strategies on the part of small farmers to assure themselves of benefits and guard against risks. In both settings, politically, we find poorer farmers weak and unable to adapt robust strategies of ensuring access to good quality seed and drugs. In the Chinese drugs case, poorer patients were largely unaware of the risks posed by the extensive, and sometimes medically inappropriate, use of antibiotics and thus informal strategies in relation to issues of risk were not an issue. In terms of access problems, poorer patients relied on barefoot doctors who were willing to provide treatment on credit or discounted rates, but who were more likely to provide antibiotics in response to patients' requests.

We also sought to identify other kinds of 'post-regulatory' initiatives that improved the reach of regulation for poorer users. As discussed in Chapter 2, 'post-regulatory' strategies imply a wider range of hybrid, indirect arrangements by which technological norms are asserted or achieved than just classical rule setting by the state. In particular, such strategies imply that regulation needs to attend to all those implicated in interventions, and extend beyond regulators to others who influence the way realities are brought into line. Indeed, as we have seen, part of the difficulty in building harmonized regulatory capacities has been that political, economic and social processes and actors key to the 'deviant' performance of the technology (relative to the regulatory norm) fall outside the frames currently included in regulation, and undermine the norms being sought. In the seeds cases in both China and Argentina, though in very different ways, this included the structure of the seed market. Whether it is the confusing proliferation of seeds in China or the monopoly of informal supply channels in Argentina, the control of intellectual property and biosafety risk needs to address the characteristics of those markets. In Chaco, the diversity of socio-technical systems of cotton production and the political power of large farmers also militate against top-down state-led attempts to impose international technological norms, whilst in Hubei and Shandong the long- standing administrative tradition of licensing firms, and the acute absence of working capital at a local level were pertinent factors. In the drugs cases, it was the incentive structures that shape medical practioners' prescribing decisions that fall outside of regulatory framings. The funding of health delivery systems, the unintended effects of controlling drug price mark-ups, the marketing tactics of drugs firms, patient expectations, and doctor/patient relationships all undermine the attainment of norms for appropriate antibiotic use (which in any case are only weakly sought). Any successful attempt to pursue 'post-regulatory' ideas will have to address these kinds of pre-existing realities.

In the seeds cases, we identified a number of such initiatives that attempted to counter perceived shortcomings in regulatory design and/or enforcement (though not in the drugs cases where neither patients, nor technology providers, nor local regulators prioritized the overprescription of antibiotics). For example, in Hubei, seed companies have taken measures to beat counterfeiters and retain seed purchasers' trust in brands, and in Chaco, Genética Mandiyú has tried (unsuccessfully) to enforce contracts with commercial farmers, and has sought to involve local government, regulators and various private actors in a proposal to formalize informal seed delivery channels. Our fieldwork also revealed a number of other options that were under discussion or were raised as possibilities. These have included, in the Argentinean seeds case, the licensing of co-operatives by the seed breeder to sell certified seed in exchange for a share of profits, and the extraction of royalties other than at the point of seed sale. These adaptive responses and ideas have emerged primarily from the private sector. The state has been absent as a guiding hand in their design. As such they have not sought to promote 'public regulatory goods' as opposed to the objectives sought by private actors. These might, but do not necessarily, improve the reach of regulation in ways that benefit poorer users, except insofar as poor users' aspirations coincide with private objectives.

Certainly, there may be advantages to looking for local governance of these technologies, to the extent that locally adapted 'post-regulatory' measures address realities on the ground, and involve actors other than the regulatory state in the design of interventions that further a regulatory objective. If regulation is the negotiated attempt by actors to intervene in complex, uncertain, partially understood socio-technical-ecological realities, then better regulatory design and capacity-building cannot limit itself to formal regulatory actors alone, but needs to tend to all those implicated in interventions, and extend to others who influence the way realities are brought into line. But there are some serious difficulties involved in relying on local responses to improve access and protect against risk, especially for poorer users, in the absence of regulation from above.

First, some such measures require cutting to the heart of health or agricultural political economy. In Argentina, this means challenging the power of the co-operatives and larger farmers over seed supply chains and that of drug manufacturers over incentive structures for doctors. In China, it means challenging the emergence of a dynamic and powerful but disorderly seed and pharmaceutical industry and recognizing the importance of perverse incentives for drug vendors and medics. The realities of local power dynamics, as we saw for example in Monsanto's unsuccessful attempt to enforce private contracts with farmers in Chaco, may undermine post-regulatory attempts at imposing certain technological norms.

A second difficulty in relying solely on locally generated adaptive approaches to regulation is that some of the (international) public good issues are forgotten or played down. In the seeds cases, the widespread and uncontrolled circulation of low quality transgenic seed raises questions about resistance amongst insect pests to the Bt toxin. Regulatory implementation is failing to stem the circulation of these lower quality versions on the ground. Neither concern nor capacity exists in either country to manage it locally anyway. Similarly, we see crop varieties in circulation that have yet to gain biosafety approval, raising questions about, for example, the capacity to anticipate and avoid potential environmental impacts, or ensure that export markets remain open. In the drugs cases, overuse of antibiotics is not a local regulatory concern, raising questions about microbial resistance. Regulatory measures that make these public good norms felt locally are still required. Ideally, the state would have the legitimate authority to arbitrate these top-down requirements with the more pressing priorities that local adaptive measures might privilege, and in the case of resistance to Bt, to make facilitating changes in local agronomic contexts.

Third, not all state-led attempts to impose national and international technological norms are unsuccessful for poorer users of seed and drug technologies. Thus, quality regulations for Argentinean drugs extend successfully to 'semi-informal' production of similar drugs and regulations. Price controls and generic prescription alongside broader health policies do ensure that there are reasonable levels of access to good quality pharmaceuticals in both countries. These are important regulatory assurances for poorer users.

Most fundamentally, however, some of the international technological norms that are being sought through emerging 'post-regulatory' initiatives, or indeed through classical top-down regulation, are often deeply contested, and the fault lines of that contestation runs between actors situated in very uneven power relations. Thus, poorer farmers in Argentina have little interest in an effectively implemented system of intellectual property along the lines sought in international norms; indeed such a system would deprive them of any means of pursuing their livelihoods. Fortunately, for smaller farmers, their interests have happened to coincide broadly with Argentina's more powerful larger farmers whose political influence has weakened intellectual property regulation and who gain comparatively greater advantage from that lacuna. But more effective 'post-regulatory' solutions to imposing international intellectual property norms would force Argentina's small cotton farmers into having to find some other source of meagre income, or push them back into relying solely on subsistence farming. In China, measures to concentrate the seed industry into a more orderly market of fewer breeders and vendors could, in the short term, prove detrimental to poorer farmers' access to seed.

Rethinking regulation in such contexts means that space must be provided for poorer peoples' concerns over the diffusion of technological benefits and risks. Of course the private good for poorer users does not necessarily equate with the public good. Rather, the task is to reframe the problem of regulation in ways that allow poorer users to participate in the negotiation of what those norms should be, and allow a capacity for reflecting upon the role of regulation in balancing those immediate and local developmental concerns with longer-term risks and global public issues. The decentred literature certainly suggests the importance of reframing problems (and system views) in creating more appropriate regulatory strategies. As we pointed out in Chapter 2, a corollary of the decentred perspective is that the variety of regulatory framings comes to the fore. If knowledge is fragmented and dispersed and different actors have different information and interpret objects and purposes differently depending on their regulatory standpoint, then the challenge confronting decentred regulation is not 'simply' piecing together all the necessary fragments of knowledge in order to provide an overall picture. Instead, the challenge is to arbitrate between incommensurable framings that prioritize, constrain and shape different features of the problem for appraisal, as well as suggesting alternative methodologies for attaining knowledge about those features, thereby engendering distinct understandings of the problem, its sustainability and 'optimum' intervention strategies for change. This involves nurturing a flexibility in regulatory approaches that adapt to local conditions and norms. In other words, the classic concerns of regulatory design and regulatory implementation, traditionally considered sequentially, need to be considered in the round, and situated as a piece in specific contexts that include broader pro-poor policies. Capacity-building, according to this view, needs to attend to and support the development of more locally specific, inclusive, and collaborative regulatory approaches able to work with the grain of the situation on the ground. These require a much more reflexive state role than we see at present in both settings.

Post-regulatory state measures that, for example, exempt Argentina's small farmers from paying seed royalties whilst nevertheless ensuring their access to quality seed, or that extend back up the technology development process, and which facilitate the upstream development of appropriate solutions to local production constraints (whether through seed breeding or other measures) are part of that more ambitious strategy. In China, discussions around the role of civil society continue, but recognized small farmers' organizations are still absent. A voice for farmers in the country's political fora could help feed concerns around regulation and innovation back to national and possibly international decision-making bodies. A more concerted focus on patient education and attention to the continued importance of barefoot doctors in rural health provision would complement ongoing health reforms. All such examples require the state to be involved in redefining the public good and calibrating the ways in which this is sought.

In sum, the challenge is to negotiate technological norms at local, national and international levels in a way that acknowledges dynamics, complexity and the diverse framings of different groups. This requires a careful and judicious balancing of regulatory state and post-regulatory state measures that is particular to the technological issue at hand, and that in turn requires a deep understanding of technological practices on the ground. One way of improving this dialogue would be to open up both national and international negotiations to the views and situation of poorer technology users. This would include institutions for monitoring implementation experience on the ground, and revising regulatory frameworks or capacity-building initiatives (and indeed agricultural innovation policy more generally) in the light of lessons learnt. Any attempt to rethink regulation should begin by seeking ideas from poorer farmers and patients. Even if they did not have direct regulatory proposals, the research presented here indicates that they will have very relevant and instructive perspectives upon seed and drug socio-technical system structures and functions, and the kinds of problems that these entail.

These kinds of proposals are quite difficult to envisage in circumstances where agricultural and health political economies currently exclude the voices of less powerful and marginalized actors, and where there are limits, set by international obligations and trading partners, on the autonomy individual jurisdictions have to devise locally appropriate technological policies. Nevertheless, it is important to point out difficulties such as those identified in this book. Taking all opportunities presented by any openings in harmonization, and new fora for debate, will be important. We hope that this book plays its small part in those opportunities.

CHAPTER 6

A Responsible Innovation Governance Framework for GM Crops

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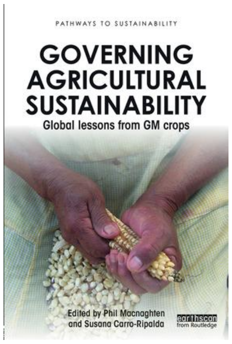

Global lessons for agricultural sustainability

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 sustain- ability. 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 environ- mental 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 environ- mental 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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