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Addressing the dynamics of agri-food systems: an emerging agenda for social science research

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ABSTRACT

The 'modernist' project that has come to dominate food and agricultural policy has failed to provide sustainable outcomes for many poor people in developing countries. Conventional agricultural science is not able to explain let alone address these concerns because it is based on a static equilibrium-centred view that provides little insight into the dynamic character of agri-food systems. This paper analyses how prevailing narratives of technological change and economic growth have come to dominate key food and agriculture policy debates. It seeks to counter these orthodox notions by emphasising that agri-food systems are embedded in complex ecological, economic and social processes, and showing how their interactions are dynamic and vulnerable to short-term shocks and long-term stresses like climate change. The paper makes the case for a deeper understanding of diverse 'rural worlds' and their potential pathways to sustainability through agriculture. Moreover, it argues for a normative focus on poverty reduction and concern for the distributional consequences of dynamic changes in agri-food systems, rather than aggregates and averages. Finally, it sets out an interdisciplinary research agenda on agri-food systems that focuses on dynamic system interactions in complex, risk-prone environments and explores how pathways can become more resilient and robust in an era of growing risk and uncertainty.

1. Introduction

In an era of rapid change and growing risk and uncertainty, agricultural policy and practice in the developing world is encountering a number of limitations which reveal inadequacies in its long-term sustainability and its capacity to meet a range of objectives. These include concerns about chronic hunger and malnutrition, adverse environmental changes, the limits of technology-enhanced productivity gains, increasing land degradation, the loss of both biological and cultural diversity, livelihood insecurity and the continuing poverty of agricultural communities. Worries about food safety, hygiene and nutrition, and growing demands for the re-localisation of agri-food systems from citizen consumers in both the North and the South have also emerged. These apprehensions raise important questions about whether the forms of agriculture developed over the past century, and celebrated as technically advanced and 'modern', are able to respond to the complex and diverse array of challenges they will encounter in the 21st century.

In this paper, we argue these concerns arise because the prevailing approach to agricultural science and innovation often fails to provide sustainable outcomes, particularly at larger scales and for large numbers of poor people in developing countries. Recent research on socio-ecological interactions in agriculture has demonstrated how human transformations and uses of the resources to produce food and fibre can cause unexpected, precipitous and possibly

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irreversible changes in the natural environment. Natural sciences have made some progress in understanding how ecological ‘surprises’ – the qualitative gaps between perceived reality and expectation – and system ‘flips’ come about (cf. Scoones et al., 2007).

By contrast, relatively little progress has been made in understanding surprises in agri-food systems, and in defining management practices that might contribute to poverty reduction and help systems become more resilient and robust in order to cope with shocks and stresses, together with the social and institutional mechanisms behind these practices. This is a major challenge for agri-food systems, and the remainder of the paper will elaborate some of the many dimensions of this. The paper outlines an interdisciplinary research agenda on agri-food systems, focusing on dynamic system interactions in complex, diverse, risk-prone environments and explores how agri-food pathways can become more resilient and robust in a turbulent age.

2. Agri-food system dynamics and sustainability

Over the past 20 years, a great deal of work on agricultural sustainability has focused on the capacity of food systems to absorb perturbations and still maintain their functions (Conway, 2007; Conway and Barbier, 1990). In a resilient and robust agri-food system, disturbances have the potential to create opportunities for doing new things, for innovation and for new pathways of development (Berkes et al., 2003; Gunderson and Holling, 2002). In a vulnerable system, even small disturbances may cause significant adverse social consequences especially for those who are most vulnerable, such as the rural poor in developing countries (Adger, 2006; Ericksen, 2008a,b). Until recently, dominant perspectives in conventional agricultural science and development programmes have implicitly assumed a stable and an almost indefinitely resilient environment, where resource flows could be controlled and nature would return to a steady state when human stressors were removed. Such static, equilibrium-centred views, we argue, provide inadequate insight into the dynamic character of agri-food systems, particularly in an era of global economic and environmental change, where factors such as climate change, rapid land use shifts and uncertain political economic conditions in agricultural economies all impinge on the day-to-day realities of poorer producers and consumers in the developing world.

Our focus here on uncertainty, complexity and diversity aims to shift attention from policies and practices that aspire to maintain the *status quo* or *control change* in systems assumed to be stable, in favour of analysis and practices that enhance the capacity of agri-food systems to *respond to, cope with and shape change* (Smit and Wandell, 2006; Berkes et al., 2003). Such responses in turn enhance the possibilities of sustaining desirable, yet diverse, pathways for development in changing environments, where the future is unpredictable and surprises are likely (Scoones et al., 2007; Folke, 2006; Adger et al., 2005; Walker et al., 2004).

Much conventional agricultural science and policy does not seem to be able to explain let alone respond to complexity, diversity, uncertainty and non-equilibrium states, although poor people who are dependent on agriculture for their livelihoods very often live in complex, diverse and risk-prone settings, with inherent seasonal instability (Devereux et al., 2008; Chambers et al., 1981). Vulnerability not only damages people’s welfare, it also reduces growth directly by destroying assets and indirectly as threats of shocks and stresses divert assets from more productive activities to those that reduce risk and uncertainty (Ericksen, 2006; Barrett and Swallow, 2004).

Agricultural and resource management problems typically tend to be classic ‘systems’ problems, where aspects of systems behaviour are both complex and unpredictable, and where causes, while at times apparently simple, when finally understood, are always multiple. These problems are often non-linear in nature, cross-scale in time and space and dynamic in character. This is true for both natural and social systems and their interactions. In fact, they need to be understood as one system, with critical feedbacks across temporal and spatial scales. Thus, interdisciplinary and integrated modes of inquiry are needed for understanding and designing effective responses to human–environment interactions related to food and agriculture in a turbulent world (Scoones and Thompson, 2009).

Yet the underlying philosophies of two contrasting streams of agricultural science are often in opposition. One stream is represented by the paradigm of molecular biology and genetic engineering (Conway and Toenniessen, 1999). This promises to provide not only health and economic benefits from agricultural biotechnology, but also an uncertain era of changing social values and consequences. This stream is a science of parts; that is an analysis of specific biophysical processes that affect survival, growth and distribution of target variables as if they were independent of each other and could be systematically controlled one at a time. It emerged from a tradition of experimental science, where a narrow enough focus is chosen to pose specific questions and empirical hypotheses, collect data and design critical tests for the rejection of falsified hypotheses. The goal is to narrow uncertainty to the point where acceptance of an argument among scientific peers is essentially unanimous. Thus, it is conservative and narrowly focused, and it achieves this by being fragmentary and incomplete. It provides individual building blocks of an edifice, but not the architectural design. This kind of approach to modern agricultural science may be suitable for certain types of conventional agricultural development but not for sustainable agriculture—if sustainable agriculture is defined more broadly to include a range of ecological, economic and social objectives, such as sustained reductions in chronic malnutrition, poverty and ecological harm.

By contrast, a holistic stream can be characterised as a science of integration; that is, by interdisciplinarity and synthesis, by cross-sectoral and cross-scale research and analyses. It is represented, for example, by agroecology, conservation biology, landscape ecology and other systems approaches that include the analysis of (agri-food)-ecosystems, the interactions between multiple co-existing populations and landscapes, and more recently, the study of socio-ecological dynamics at different scales (and concerns about climate change). The applied forms of this stream have emerged regionally in new forms of integrated agricultural practice and natural resource and environmental management, where uncertainty and surprises become an essential part of an anticipated set of adaptive responses (Altieri, 2002, 1995; Conway, 2007; Lee, 1993; Walters, 1986; Holling, 1978). They are fundamentally about blending disciplinary perspectives and combining historical, comparative and experimental approaches at scales appropriate to the issues. It is a stream of investigation that is fundamentally concerned with integrative modes of inquiry and multiple sources of evidence.

The premise of this holistic stream is that in agricultural science, knowledge of the system we deal with is always incomplete and patchy (Kerkhoff and Lebel, 2006; Thompson and Scoones, 1994). Surprises are inevitable and must be anticipated. They come about when causes and effects turn out to be sharply different from what was conceived, when behaviours are profoundly unexpected and when actions produce results different to those intended. Not only is our science almost inevitably incomplete, the system itself is a moving target, evolving because of the impact of management and the progressive expansion of the scale of human influences on the environment. In principle, therefore, evolving and dynamic agri-food systems and the societies with which they are linked involve incomplete knowability and partial predictability. What is needed, therefore, are policy-making processes that are fair; fair to people, fair to the environment and to future generations.

Thus, 'sustainable development' – and with it, 'sustainable agriculture' – is also only partly knowable and predictable. How it develops will depend on decisions and actions that have yet to be taken, and requires processes of reflexive deliberation at the centre of analysis and action. And therein lies a key issue that we must address at the core of contemporary agricultural science and innovation. Dynamic and diverse agri-food systems require policies and actions that not only contribute to social objectives, like poverty reduction, but also achieve continually modified and enriched understandings of the evolving ecological, economic, social and political conditions and provide flexibility for adapting to surprises. Through this process, agricultural science, policy and management become inextricably linked, as diverse socio-technical systems are explored in multiple pathways to sustainability.

3. Drivers of change: the contemporary characteristics of agri-food systems

If a consideration of dynamic uncertainty needs to be at the core of any search for sustainable solutions to developing world agriculture, what, then, are the factors that drive change and create risks and uncertainties in developing world agriculture today?

Agriculture is an important source of livelihoods in developing countries, providing ways of life for billions of people, many of them poor. Of the world's 6.5 billion inhabitants, 5.5 billion live in developing countries, 3 billion in the rural areas of these countries (World Bank, 2007). Of rural inhabitants, an estimated 2.5 billion are involved in agriculture, 1.3 billion are smallholders, while others include farm labourers, migrant workers, herders, fishers, artisans and indigenous peoples who depend on agriculture and natural resources for their livelihoods. More than half are women. The developing world will remain predominantly rural until around 2020 and millions of poor people in those countries will continue to rely on agriculture for their livelihoods for the foreseeable future (Thompson, 2006).

Given these trends, chronic hunger and global food security will remain a worldwide concern for the next 50 years and beyond, as the world's population grows from its current 6.5 billion to upwards of 10 billion, most of whom will reside in developing countries.

3.1. *Changing drivers*

One response to these pressures is to argue for a technology-led Green Revolution, replicating the success of the boosts in agricultural productivity achieved in some parts of the world during the 1960s and 1970s. However, the challenges faced today are substantially different. Since the 1980s, there has been a substantial decline in public sector support for agriculture and many producers have lost access to key inputs and services. While public sector provision of these services was never very efficient, it often provided the linkages to markets for poor rural producers. Today, such links are tenuous and complicated by much greater integration of the global economy. Smallholder producers now compete in global markets that are much more demanding in terms of grades and standards (e.g., quality, traceability and food safety), and more concentrated and vertically integrated than in the past (Vorley, 2003; Reardon et al., 2003; Reardon and Barrett, 2000). Today, the system is becoming much more complex, starting with a firm's involvement in (bio)technology, extending through agro-chemical inputs and production, and ending with highly processed food (Bonnano et al., 1995; McMichael, 1994). Increasingly, these firms are developing a variety of different alliances with other players in the system, forming new food system 'clusters' (Heffernan et al., 1999).

Because agriculture has a larger tradable component than most sectors, it is profoundly affected by the trade environment and trade policy. Whereas overall trade barriers in industrial countries have declined significantly over the last decade, the remaining barriers are concentrated on agricultural products and labour-intensive manufactures in which developing countries have a comparative advantage. High levels of farm support, at the level of US$ 279 billion or EUR 226 billion per year in countries belonging to the OECD, depress world prices for several key commodities (especially sugar, cotton, milk, and beef) and deeply undermine agricultural growth in developing countries (OECD, 2005). Quotas and tariffs remain important instruments for protection, and sanitary and phytosanitary restrictions increasingly perform the same function. Tariff rate quotas, for example, still protect 28% of OECD's agricultural production (a figure that is probably underestimated) (cf. de Gorter and Hranaiova, 2004).

Global and regional economic integration is accompanied by other challenges that further weaken the socio-economic position of the rural poor. In some parts of the world, especially in Sub-Saharan Africa, rural areas are hard hit by the HIV/AIDS pandemic, which is disrupting the transfer of knowledge, destroying traditional land allocation systems, and dramatically changing the demographic composition of many rural communities (Edström et al., 2007; UNAIDS, 2006). Rising energy prices are driving massive investments in biofuels, which could increase the volatility of food prices with negative food security implications in some regions (UN-Energy, 2007). Finally, conflict conditions, many of which result from or are provoked by poverty, are further eroding the livelihood systems and resilience of poor rural people (Richards, 2006; Flores, 2004).

Global environmental change – especially through shifts in the climate (IPCC, 2007) – is increasing pressure on an already fragile natural resource base in complex, risk-prone environments that are the mainstay of rural livelihoods (Ericksen, 2008a,b; Tilman et al., 2001). Most models suggest that climate change will slow or reverse the poverty-reducing impact of agriculture, with, by one estimate, some 600 million additional people at risk of hunger if temperature increases by over 3 °C (Warren et al., 2006). But this has to be set against other changes in agriculture such as improvements in technology and changes in farming systems (Fischer et al., 2005).

A recent study of 23 climate models in *Science* (Battisti and Naylor, 2009) predicts that by 2090, elevated temperatures will not only cause excess evaporation but also speed up plant growth with consequent reductions in crop yields in many regions. Although rising temperatures may initially boost food production in temperate latitudes by prolonging the growing season, crops will eventually suffer unless growers develop heat-resistant versions that donot need a lot of water. The authors predict future production reductions of 20–40%, while the population in tropical regions is expected to double to 6 billion. Further, extreme events such as floods and droughts are likely to become more severe and frequent over the next century under all scenarios and for most land areas.

These trends are not helped by the fact that attention to agriculture in terms of policy commitments and investment levels declined in real terms over the past 20 years in both international donor and developing country policies and programmes, despite the demonstrated high rates of return and the reductions in poverty that come from such investments (Fan et al., 2001; Alston et al., 2000). Further progress is curtailed by weaknesses and deficiencies in agricultural science and technology policy regimes that result in institutional arrangements and organisational architecture – from the Consultative Group of International Agricultural Research Centres (CGIAR) to national agricultural research systems – unsuited to development and broad-based diffusion of poverty-reducing innovations (Scoones and Thompson, 2009; Byerlee and Alex, 1998).

Thus agri-food systems are changing as a result of the complex, dynamic interactions of a range of environmental and socio-economic drivers: from climate change, agricultural intensification, concentration of production, vertical integration and coordination to industrialisation, deregulation and economic liberalisation and urbanisation (Thompson et al., 2007; Pimbert et al., 2003; Vorley, 2002). Given the diversity, uncertainty and complexity of contemporary drivers of change and the range of different contexts within which agriculture is an important source of livelihood and economic activity in the developing world, how has agricultural science and policy responded?

4. Dominant narratives of agricultural science and policy: technology and growth

Two intersecting narratives – centred on technology/production and economic growth – have dominated policy discourses and influenced the trajectory of agricultural development over the past 60 years. The term 'narrative' is used here to emphasise the constructed nature of these framings of particular problems and their socio-technical solutions, and the attachment of those narratives to certain actors (e.g., particular policy narratives or the narratives of particular social groups). Therefore we can talk about dominant or mainstream narratives associated with powerful actors and networks and alternative narratives that represent more marginal, minority voices which represent competing framings of problems and solutions. In this section we examine two dominant narratives of 'progress' in agricultural science and policy, which not only suggest particular (sets of) pathways for agricultural development, but also raise some important epistemological and governance questions. For example, how do these long dominant perspectives frame and structure debates, and in so doing include and exclude other alternative perspectives? How do they respond to the challenges of dynamic change and complexity in agri-food systems? And how do they frame debates about sustainability?

4.1. *The production–innovation narrative*

One of the most compelling core narratives framing agricultural policy and practice relates to the application of scientific knowledge to agriculture, linked to a linear view of modernisation, often influenced strongly by Malthusian concerns about increasing food production to meet growing populations and avert famine. The standard model of an 'Agricultural Revolution' is usually taken to imply a dramatic increase in both output and productivity. This first took place in England during the century after 1750 and ran in parallel with and reinforced the Industrial Revolution (Overton, 1996), a time when famine was still common in Europe. From the mid-18th century onward English and later French agriculture were able to feed an unprecedented rise in population. The rise in labour productivity meant that a smaller proportion of the workforce was engaged in farming and therefore a larger proportion was available to work in industry. In turn, an increasing urban population drove the need to increase yields and improve agricultural efficiency even further. The twin effects of agricultural technological innovations, particularly fertilisation improvements and mechanisation, enabled a doubling of the world's population.

The ''Green Revolution'' was a phrase coined to refer to the development of so-called 'miracle seeds' – the high yielding (or at any rate highly responsive) varieties (HYVs) especially of wheat and rice, which held out the prospect for spectacular increases in cereal production and the transformation of developing world agriculture. This transformation occurred as the result of programmes of agricultural research, extension and infrastructural development, instigated and largely funded by the Rockefeller and Ford Foundations, along with other major agencies from the 1940s to the 1960s (Dowie, 2001). While the meaning and consequences of the Green Revolution remain contested issues, the key elements of its technological thrust are undisputed: the set of production practices for farmers in developing countries rested on the development of Mendelian genetics, applied plant breeding, the ability to manufacture and market inexpensive nitrogen fertiliser (cf. Smil, 2004), and the controlled supply of water through irrigation technologies.

Since the 1990s, a state-led approach to agricultural development has given way to a much stronger emphasis on private sector provision – both private companies and NGOs – but the mix of technologies remains remarkably similar. Today, HYVs are grown worldwide – including roughly 95% of the rice in China and Korea, and 70% of the rice in India and the Philippines – and there is no question that the rate of growth of food output per capita has exceeded population growth rates in the developing world since 1950 because of the productivity gains of the Green Revolution (Smil, 2004; Conway, 1997; Lipton and Longhurst, 1989).

In the first phase of the Green Revolution, a number of important technical and socio-economic problems emerged, including those associated with: pest and weed control, post-harvest storage and processing and ecological deterioration (particularly loss of germplasm, water depletion and toxicity). At the heart of this impact question are issues of the governance of science and technology and questions of equity, poverty and social justice.

The Green Revolution has undoubtedly increased aggregate food output per capita and enabled agricultural production to keep pace with population growth, both more than doubling since the 1960s. But this has often neither increased food availability for the poor (Drèze and Sen, 1989) nor improved the lot of many poor farmers and farmworkers (Evenson and Gollin, 2000). Furthermore, the revolution brought with it a wide array of environmental problems. Monocropped cereals required tight control to maintain their stability. Control of crops and their genetics, of soil fertility via chemical fertilisation and irrigation, and of pests (weeds, insects and pathogens) via chemical pesticides, herbicides and fungicides – the hallmarks of the Green Revolution – affected agroecosystems by the use and release of limiting resources that influence ecosystem functioning (i.e., nitrogen, phosphorus and water), release of pesticides and conversion of natural ecosystems to agriculture. This prevailing form of agriculture caused a significant simplification and homogenisation of many of the world's ecosystems, affecting both biological and cultural diversity (Pretty et al., 2008).

Despite these shortcomings, the production–innovation narrative that underpins the Green Revolution continues to enjoy wide currency in policy and scientific circles. There is debate over whether the first phase of the revolution has continued or ended, since there have been no new seed breakthroughs in productivity levels in the world staple crops in recent years. Nevertheless new efforts are underway to launch a 'New Green Revolution for Africa', which might include many of the same technology-focused attributes as Asian Green Revolution.[1] In addition, the Green Revolution has entered a second phase associated with recent breakthroughs in molecular science and recombinant DNA. This so-called 'Gene Revolution' is much more focused on private capital and coordination of biotechnology than on state-led support of the development and distribution of global public goods in the form of new hybrid seeds (cf. Brooks, 2005; Seshia and Scoones, 2003). As with the first Green Revolution, questions must be asked whether this Gene Revolution must also come as relatively expensive packages, and therefore risk amplifying inequalities further, or whether there is or could be a 'pro-poor' GM technology, and if so, the conditions under which it might be developed (Spielman, 2006; Chataway, 2005).

4.2. *The growth narrative*

A second, equally powerful narrative focuses on the role of agriculture as an 'engine of economic growth' and is frequently based on evolutionist assumptions about the economic and social transformation of the agrarian economy – from backward to modern, from subsistence to market-orientated, from the 'old' to 'new' agriculture (World Bank, 2005, 2007; OECD, 2006). While this narrative incorporates key dimensions of the production and innovation narrative described above (as part of the transformative elements needed to bring about change), its emphasis is firmly on the catalytic role of agriculture. The central argument is that no country has been able to sustain a rapid transition out of poverty without raising productivity in its agricultural sector (Lipton, 2005). Much of this debate has been led not by agricultural scientists and engineers, but by economists and development theorists. Consequently, it has influenced the policies and programmes of key international development agencies, particularly the Bretton Woods institutions of the World Bank and the International Monetary Fund.

By emphasising expenditure linkages – especially through consumption – Johnston and Mellor's work (1961) countered the argument that growth linkages are low in small-scale agriculture because of relatively low use of external inputs. Using an array of techniques ranging from simple input–output and expenditure models to more complex social accounting matrices, multi-market models and village and regional computable general equilibrium (CGE) approaches, this research showed that growth in agriculture does indeed generate rural non-farm growth and growth in the wider economy. Generally speaking, however, it was not until the mid-1960s – in parallel with the emergence of the production–innovation narrative centred on the Green Revolution – that development professionals began to view agriculture as an important component of economic growth. In this period, as discussed above, agricultural development placed heavy emphasis on direct transfer of agricultural technology from industrialised to developing countries. The U.S. agricultural extension system was widely touted as a vehicle for accomplishing this goal, with emphasis on the diffusion

[1] Alliance for a Green Revolution in Africa (AGRA) is a joint initiative of the Rockefeller Foundation and the Bill and Melinda Gates Foundation committed to reducing hunger and poverty in Africa through agricultural development.

or Transfer of Technology (TOT) model to poor producers (Ruttan, 1998).

Despite the call to ''get agriculture moving'' (from Mosher, 1966 onwards), the very opposite took place. Up to the 1980s, agricultural producers were widely taxed by a variety of distortionary policies (Krueger et al., 1991). Macroeconomic policies that overvalued exchange rates and protected import-substituting industries that were then common had especially severe negative impacts on the agricultural sector, which produces largely tradable commodities. Within the agricultural sector, widespread intervention through parastatal institutions that taxed export crops and held down food prices in the interests of urban consumers also reduced incentives for farmers. Numerous studies have shown the high costs of these policies to agriculture and ultimately to the rural poor; what Michael Lipton termed 'urban bias' (Lipton, 1977). From the 1980s, many developing countries implemented 'stabilisation' and 'structural adjustment' policies under the guidance of the World Bank and IMF that substantially improved the macroeconomic environment in terms of liberalised imports, a market-based exchange rate and greater fiscal discipline and reduced inflation. However, their record of liberalisation in the agricultural sector itself was ambiguous and their impact on poverty, food security and hunger was decidedly mixed (Sahn et al., 1997).

Despite this apparent lack of interest and investment in agriculture and rural development, agriculture-led growth has recently returned to the top of key international development agendas. With agriculture still the key sector in many developing economies, getting agriculture onto a growth path is increasingly the core theme of policy documents, both from international donors and national governments. Whether in the context of the World Bank's (2007) recent *World Development Report* for 2008 on agriculture for development, the OECD's (2005) Poverty Network report on agriculture or the UK Department for International Development's agricultural policy paper (DFID, 2005), emphasis now is being placed on efforts to develop 'pro-poor' agriculture that is also 'pro-growth'.

Why has this growth-focused agricultural narrative re-emerged with such renewed vigour? The policy message that surfaces from this now substantial body of work is clear: increases in productivity in small-scale agriculture can result in broader gains to the wider economy, with spin-offs to the rural non-farm sector. In time, the argument goes, this will result in a transition from a broadly subsistence-based agricultural economy to one which can afford more inputs and become more commercial, specialising along the way – if directed by demand – into high-value niche commodities and global markets. As the sector's fortunes improve, the opportunities for exit from agriculture will increase as off-farm opportunities grow (e.g., in farm labour, agro-processing and the rural service sector). Such growth will create an economic 'pull' – rather than the current situation of being pushed out from a failing agriculture. The end result, it is argued, will be a vibrant, fully modernised integrated economy, with a small but efficient agricultural sector continuing to generate growth and employment.

That at least is how the standard version of the current 'pro-poor agriculture growth' narrative represents its analysis and perspective. But what are the problems with this simple account, so often repeated in current policy debates? If the relentless economic logic is so powerful, why hasn't it already happened in large parts of the developing world, including Africa? And is there really only one pathway for such a complex process?

Debates on economic growth and agriculture are manifold, but some important qualifications and critiques to the standard growth narrative can be identified. Firstly, are the models that generate this account sufficiently realistic? Models, such as social accounting matrix (SAM) models (cf. Vogel, 1994) and even more complex, economy-wide multi-market (EMM) and CGE models (cf. Diao et al., 2007) are of course only as good as the assumptions and the data on which they are built, and in the case of growth linkage models these are open to question (Haggblade et al., 1991). It is, however, less the technical and data limitations of the models that are of concern than the way they frame and influence the policy debate. Showing that what is (vaguely) defined as 'commercial' or 'modern' farming generates a significant value-added share and so overall growth benefits provides the 'evidence' for the policy recommendations from both government and donors. This 'evidence', in turn, is interpreted as implying a particular type of investment and support for a particular approach to the commercialisation of agriculture.

Secondly, such discussion – reinforced by such models – is often wrapped up in another argument that there are somehow a defined uni-linear set of 'stages of growth', involving singular trajectories to some desired end (usually away from a backward, subsistence form of farming towards something better, more modern and commercial). A familiar argument since Walt Rostow's famous '*Stages of Growth*' thesis (1960) is that economic development consists of a series of clearly defined steps or 'stages', and that the challenge is to find the technology, institutional instruments and market incentives to push things from one stage to the next (Rostow, 1960). But such stagist-evolutionist arguments of a somehow necessary move from one stage to the next can also be questioned, as they focus narrowly on the aggregate benefits of growth rather than on broader distributional aspects, such as who acquires those benefits, and whether there might be other alternative pathways out of poverty.

5. Alternative narratives: challenges to the dominant perspectives?

Despite the dominance of the production–innovations and growth perspectives, there are a number of well-documented alternative narratives to conventional agriculture that have emerged over the past two decades. Two of these, one emphasising agroecology and the other participation, have gained considerable traction in some policy quarters, though, until recently, they tended to be advanced by less mainstream actors.

5.1. *Agroecological alternatives*

In recent decades, farmers and researchers around the world have responded to the extractive industrial model with ecology-based approaches, variously called 'alternative', 'sustainable', 'natural', 'low-input', 'low-external-input', 'regenerative', 'holistic', 'organic', 'biointensive', and 'biological' farming systems. All of them, representing thousands of farms and farming environments, have contributed to an understanding of what sustainable agri-food systems are, and each of them shares a vision of 'farming with nature', an agroecology that promotes biodiversity, recycles plant nutrients, protects soil from erosion, conserves water, uses minimum tillage, and integrates crop and livestock enterprises on the farm.

Agroecology has emerged as the discipline that provides the basic ecological principles for how to study, design and manage alternative systems that address not just environmental/ecological aspects of the crisis of modern agriculture, but the economic, social and cultural ones as well (Rickerl and Francis, 2004; Altieri, 1995). It seeks to go beyond a few-dimensional view of agroecosystems – their genetics, agronomy and profitability – to embrace an understanding of ecological and social levels of co-evolution, structure and function. Instead of focusing on a few particular components of the agroecosystem, it emphasises the interrelatedness of multiple system components and the complex dynamics of socio-ecological processes. Agroecological approaches do not stress boosting yields under optimal conditions as Green Revolution technologies do, but rather they assure stability, resilience and thus sustainability of production under a whole range of soil and climatic conditions and most especially under marginal conditions (Conway, 1985, 2007).

In addition to a focus on integrated biological processes, current trends among advocates of agroecology include tapping into the knowledge and skills of farmers to understand and respond to the changing ecological dynamics of local agri-food systems. Knowledge-based innovations responding to local conditions with local resources are, it is argued, to be preferred. In addition, such technology can be generated and promoted through learning techniques that build farmers' human and social capital. This work links up with interest in what is variously termed 'indigenous technical knowledge' (ITK), 'rural people's knowledge' (RPK), and 'ethnoscience' extending back to the 1970s in development (cf. Howes and Chambers, 1979), and many important strands of later work (Warren et al., 1995; Scoones and Thompson, 1994; Richards, 1985; Brokensha et al., 1980).

Increasingly, agroecological approaches seek to manage landscapes for both agricultural production and ecosystem services, both of which can contribute positively to increasing system productivity. For example, Pretty et al. (2006) examined 286 completed and ongoing farming projects in 57 developing countries. Using questionnaires and published reports, they analysed the projects and then revisited 68 of them 4 years later to assess the extent to which they had increased productivity on 12.6 million farms, while improving the supply of critical environmental services. The average crop yield increase was 79%. Pretty and his co-authors argue "there are grounds for cautious optimism, particularly as poor farm households benefit more from their adoption" (2006: 1114).

However, there are always complex trade-offs between the availability of household labour (and the gendered dynamics of this), and health status (through the impact of HIV/AIDS for instance), markets for hired labour, off-farm income earning and migration and other agricultural activities. Equally, access to skills and knowledge may also be socio-economically differentiated, especially with the decline in coverage of state run agricultural research and extension systems, and the greater reliance on private sector input supplier and dealers, who make their money from simple input packages (of seeds and fertilisers), and not complex combinations of technology, skills and knowledge (Tripp et al., 2005, 2006). Low-external-input technologies are in many respects no different to any other technology with different inputs. Their reification in multiple NGO projects and the focus on their spread and scaling up has perhaps missed the wider debate about how to encourage appropriate innovation systems that respond to the diversity of needs of highly differentiated farming communities, and how, through such processes, to offer a wide range of technology choice through various combinations of routes – public and private, group-based and individual, deploying scientific and indigenous knowledge (Scoones and Thompson, 2009).

5.2. *Participatory alternatives*

As we have seen, approaches centred on agroecological principles demonstrate that uncertainty, spatial variability and complex ecological dynamics are essential properties of agri-food systems, highlighting the need for integrated responses and adaptive management practices in which farmers and local resource users play a central role in research and development processes.

A focus on farmer participatory research and development emerged in response to the many well-documented failures of technology transfer in the 1970s and 1980s and sought to reconceptualise the agricultural research and development process to focus on participatory technology development. The core aim was to put farmers at the centre of the innovation process, working in collaboration with scientists to design new technologies and to adapt existing ones to local circumstances. Advocates argued for a recognition of the value of local knowledge, moving away from the image of farmers as passive recipients of externally derived technology, to involve them as active, creative partners in technology development processes (Chambers et al., 1989). Thus, as Richards (1985, 1989, 1993) has observed, the art of farming is more like a skilled and knowledgeable 'performance', and rarely a simple routine operation. This is perhaps especially so with low-external-input and agroecological systems, where knowledge and labour serve as a substitute for external inputs.

Today, a wide array of people-centred approaches fall under the banner of participatory alternatives, including: farmer participatory research, participatory technology development, participatory action research, participatory rural appraisal, gender analysis, stakeholder analysis, community-based natural resource management and the sustainable livelihoods approach. These diverse yet interrelated approaches represent a pool of concepts, methods, principles and attitudes and behaviour that potentially enable poor rural people to engage directly in the processes of research and development to understand and improve their own agri-food systems. They start from an assumption that, unless and until the perspectives of poor men *and* women farmers, herders and resource managers (and the rural poor more generally) are taken into account in formulating agricultural science and technology R&D agendas and policies, the output of those efforts in research and innovation will not effectively contribute to improving agricultural productivity or reducing poverty. Their underlying goal is to seek wider and meaningful participation of stakeholder groups in the process of investigating and seeking improvements in local situations, needs and opportunities.

A strong critique of the conventional organisation of agricultural R&D has emerged. This argument points out that if research develops and transfers technology in a linear, top–down fashion to farmers – the TOT model – very often these technologies and practices are found to be inappropriate to the social, physical and economic setting in which farmers have to operate. At the very least such technologies needed complementary organisational, policy and other changes to enable them to be put into productive use. One particularly important area of work in the field of participatory development of agricultural technology has been Participatory Plant Breeding (PPB), which grew out of a series of attempts to respond to the specific cultural and ecological contexts of local farming livelihood contexts, taking into account indigenous knowledge and practices. It has shown some success in bringing about yield increases in rain-fed agroecosystems, particularly in dry and remote areas. Farmer participation can be used in the very early stages of breed selection to help find crops suited to a multitude of environments and farmer preferences (Sperling et al., 2001).

However, the manner in which local challenges can be addressed by and with the rural poor should take into account not only the indigenous knowledge and practices, but also the dynamics and governance issues at high scales, including the national, the regional and the global. This is particularly true at a time when farmer participatory research and technology development is being undertaken in increasingly globalised, privatised research systems. Thus, it is necessary to take into account how the interests of different actors, both within political elites and in civil society, will shape the participatory R&D process by active implementation, acquiescence, rhetorical gestures or resistance.

6. Competing visions of sustainability

The 'modernist' project that has come to dominate food and agricultural policy has failed to provide sustainable outcomes for many poor people in developing countries. Despite the power of its underlying production-growth narratives, conventional agricultural science is not able to explain let alone address these concerns because it is based on a static equilibrium-centred view that provides little insight into how agri-food systems are embedded in complex ecological, economic and social processes, or how their interactions are vulnerable to short-term shocks and long-term stresses. Even the compelling counter-narratives and approaches from agroecology and participatory research and development are not fully able respond to the dynamic character of complex and rapidly changing agri-food systems.

Given this, how then do we respond to the challenges of sustainability in a dynamic world? Any such discussion, we suggest, must address four core challenges.

6.1. *Dynamic human–environment interactions: framing the sustainability challenge*

Contemporary agriculture, whether small-scale or large-scale, north or south, must face an increasing array of challenges from natural processes. Whether this is new pests and diseases, soil nutrient depletion or salinisation or water scarcities, there are a range of new dynamic interactions and drivers. Climate change and the impacts of increased variability of rainfall are present particular challenges, especially in drier, rain-fed cropping systems. But there are also dynamic interactions between agriculture, health and disease, with potentially profound effects on agricultural sustainability. For example, increases in vector borne diseases (such as malaria or avian flu) or the prevalence of major epidemics (such as HIV/AIDS) have serious consequences for agricultural development pathways. Thus, it is the dynamic interactions between nature and society (e.g., climatic, agronomic and disease dynamics) that need to be taken seriously in thinking about future socio-technical trajectories. Given the complex, non-linear dynamics involved, questions must be asked in turn about the dynamic functioning of systems, and their properties – in particular how resilient, robust durable and stable are different options (Scoones et al., 2007). Singular solutions are inherently implausible, and diverse options associated with different pathways – incorporating elements of all four of core narrative outlined above in different configurations in different places – are inevitable. Such choices are clearly intrinsically political, requiring inclusive forms of deliberation on agri-food futures. This requires an analysis of and reflections on different framings involving deliberations among the key actors involved (farmers, consumers, processors, R&D players and others). Such debates must ask questions about the objectives and outputs of the system, and the trade-offs and conflicts involved, now and in the future.

6.2. *Beyond the Green Revolution: technology challenges*

As the standard 'Green Revolution' models of technology development have failed to deliver, particularly in Africa, and failed to keep up even where they previously had delivered. Newer versions of the technology-fix approach, including those currently available from biotechnology, offer solutions only at the margins and to affluent commercial farmers, consequently a wider search for different socio-technological solutions and innovation pathways is needed. As argued by those advocating agroecological and participatory alternatives, going beyond the technical focus to a wider appreciation of agricultural practice, skill and performance (*mêtis*) is needed (Scott, 1998; Richards, 1989, 1993). This in turn requires a rethinking of the way agricultural technology development occurs – from upstream priority setting to research testing to downstream extension and delivery. But given the current structure of agricultural R&D systems, and the 'locked in' and path-dependent character of existing innovation systems, it also presents a fundamental re-examination of the governance of science, technology and innovation in the agri-food sector.

6.3. *The politics and governance of food and agriculture*

Addressing these governance challenges means a focus on the politics of food. In each of the narratives of agricultural development discussed in earlier sections this is remarkably absent. But as the power and control of corporate agriculture increases or the importance of OECD tariffs or trade and subsidy regimes intensifies, such international, political issues are increasingly pertinent. These issues are central to a fierce debate about the terms of globalisation, and its impacts on agriculture, voiced by numerous groups in debates over subsidy regimes and WTO rules. With a changing political and trade geography other voices are being heard through the influence of such major players as India, China and Brazil where agriculture plays a central role in their economies. Yet with this new emerging geopolitics, questions must be raised about which pathways are being promoted to whose benefits. It is of course not only state-centred economic blocs that are having an influence over debates about agricultural futures. Citizen-consumers globally are having an impact on choices. Citizen-led campaigns which seek to reclaim control over their food systems argue for 'food sovereignty', local production/consumption, 'good' food (e.g., organics, food miles, and fair trade), raising cross-sectoral concerns about health (e.g., in relation to debates about obesity and GM foods) and the environment (e.g., pollution and agrobiodiversity). Key questions include what influences the framings of 'the problem'? How inclusive and deliberative are the policy processes that define what agriculture is for – and who it is for? What governance processes influence both system properties and their dynamics and the broader context? What pathways are constrained by current arrangements, and what options might be opened up – with what implications for sustainability – if alternative governance arrangements were envisaged?

6.4. *Exploring multiple pathways*

Given the diversity of 'rural worlds' and the importance of history and context for agricultural change, a variety of possible future pathways for agri-food systems open up. Such pathways, linking social, technological and ecological elements, potentially cover the full range from 'high market modernist agriculture' through a range of other 'future agricultures'. Different possibilities exist for different people in different places, requiring a highly located, context-specific assessment rooted in understandings of both ecological dynamics and governance settings. Some possible futures may be highly constrained, given existing conditions, and others may be accepted as the 'right' path. But a broader assessment requires an opening up of such debate, unlocking biases and constraints, both intellectual and practical. Exploring future scenarios in different settings, across diverse stakeholder groups, represents an important challenge – both methodologically and practically – but needs to be at the heart of any analysis. For only with such an open and reflexive process can alternative pathways towards sustainability be both envisaged and realised. Such analyses must of course cut across scales. While individual farmers in particular places may be our empirical focus, their options and opportunities must be understood in relation to processes interacting across scales, from the very local to the global. A pathway being pursued at one level may interact – positively or negatively – with options at another level, thus the interconnections between individual, household, region, nation and globe are critical. Too often our analyses begin and end at one scale, and fail to explore such interactions. This requires us to step out of the disciplinary boxes that define and frame much analysis and make the connections across these. Thus, for example, we need to link analyses of household food and livelihood systems with those of global environmental change.

Taken together, these challenges highlight some important new dimensions for the discussions of sustainability in agri-food systems. None of the existing policy narratives for agricultural development address them all. In response, we argue for the need to engage with at least two strands of thought that have been developed rather separately in the past. The first involves rethinking agricultural development, using a systems perspective that emphasises non-equilibrium dynamics, spatial, temporal and cultural variation, complexity and uncertainty. The second strand involves rethinking agricultural-related natural and social sciences by focusing on agroecological interactions, principles and histories and situated analyses of 'people in places'. When woven together in an integrated fashion, these two strands can, we argue, provide a rich understanding and insight into new and potentially more sustainable pathways in agri-food systems, alongside an interdisciplinary research agenda on agri-food systems that focuses on dynamic system interactions in complex, risk-prone environments and explores how pathways can become more resilient and robust in an era of growing risk and uncertainty.

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