Agri-Food System Dynamics: pathways to sustainability in an era of uncertainty

STEPS Working Paper 4

Correct citation: Thompson, J., Millstone, E., Scoones, I., Ely, A., Marshall, F., Shah, E. and Stagl, S. (2007) *Agri-food System Dynamics: pathways to sustainability in an era of uncertainty*, STEPS Working Paper 4, Brighton: STEPS Centre

First published in 2007

ISBN – 13: 978 185864 653 7

Thanks to Dominic Glover and Harriet Le Bris for help with copy-editing and to

Robert Chambers, Melissa Leach and Geoff Tansey who kindly provided peer reviews.

Design by Wave (www.wave.coop) and Barney Haward

Printed by MCR Print (www.mcrprint.co.uk)

For further information please contact: STEPS Centre, Institute of Development Studies, University of Sussex, Brighton BN1 9RE, UK

Tel: +44 (0)1273 876808

Email: steps-centre@ids.ac.uk

Web: www.steps-centre.org

CONTENTS

LIST OF FIGURES

LIST OF BOXES

LIST OF APPENDICES

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 the range of objectives that it is expected to deliver. These include concerns about chronic hunger and malnutrition, adverse environmental changes, the limits of technology-enhanced productivity gains, increasing land degradation and the loss of biodiversity, 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 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. STEPS Working Paper 1 on Dynamics). 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 the STEPS Centre work on agri-food systems, and the remainder of the paper will elaborate some of the many dimensions of this. In the following section we examine the dynamic character of agri-food systems and contend that modern agricultural science is ill-equipped to address issues of complexity, diversity and uncertainty. In Section 3 attention is turned to examining the causes and consequences of key economic, ecological and social forces that are driving change in food systems, with a particular focus on developing country contexts. Section 4 sets out the characterising features of agriculture that make it distinct from other sectors. Attention is then turned to understanding the 'five rural worlds' that broadly represent the diversity of agriculture-related livelihood strategies found in most developing contexts and their potential pathways to sustainability.

In Section 5, we analyse how the prevailing narratives of technological change, on the one hand, and economic growth, on the other, have come to dominate key food and agriculture policy debates. We then go on to examine two emergent narratives related to agroecological and participatory alternatives in Section 6 which seek to counter these orthodox notions of agricultural development and change. The strengths and weaknesses of these competing visions of sustainability are compared and contrasted in Section 7. We contend that any discussion of the sustainability of agri-food systems must address a number of challenges characterised by different aspects of system dynamics and governance.

Finally, the paper concludes by outlining an interdisciplinary research agenda on agri-food systems for STEPS. This focuses 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 2006a). Until recently, dominant perspectives in conventional agricultural science and development programmes have implicitly assumed a stable and 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 on uncertainty, complexity and diversity is at the core of the STEPS Centre agenda, and 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 Wandel 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 (Folke 2006; Adger, et al. 2005; Walker, et al. 2004; Gunderson, et al. 1995).

ORTHODOX EQUILIBRIUM VERSUS HOLISTIC DYNAMISM

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 (Chambers 1991; Chambers, et al. 1981). Vulnerability not only damages people's welfare, it also reduces growth, both directly by destroying assets and indirectly as threats of shocks and stresses cause assets to be diverted assets from more productive activities to those that reduce risk and uncertainty (Ericksen 2006a).

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 (see STEPS Working Paper 1 on Dynamics). 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 (cf. Ericksen 2006b).

A critical minority of policy-makers and citizens – both producers and consumers – are demanding integrated solutions that address these issues of uncertainty, diversity and complexity. Their calls for action are not so much driven by prophesies of doom as by the need for understanding and action. But if you seek understanding, to whom do you turn for information and advice? Agricultural science often provides only limited assistance, largely because it includes not only conflicting voices – witness the debate on genetically modified (GM) crops or arguments over food production vs. population growth – but also conflicting modes of inquiry and criteria for establishing the trustworthiness of different lines of argument.

In particular, the philosophies of two streams of agricultural science are often in opposition. The tension between them is now evident in biology. One stream is represented by the paradigm of molecular biology and genetic engineering (Conway and Toenniessen 1999). This stream of science 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 (cf. STEPS Working Paper 3 on Designs). 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, a science of the parts, 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 inter-disciplinarity 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 global environmental change, such as 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.

This stream has the most natural connection to related debates about systems dynamics in the social sciences that are in turn linked to questions of incertitude and its implications, moving beyond narrow, probabilistic notions of risk (Winterfeldt and Edwards 1986) to a broader understanding of uncertainty (Funtowicz and Ravetz 1990), ambiguity – where different people or institutions circumscribe a problem from contrasting perspectives (Stirling 2006; 1999) and ignorance, where we don't know what we don't know (Wynne 1992). These challenges require more nuanced, qualitative understandings of causality and change, attending to ethnographic understandings of place-specific processes, the particular dynamics of knowledge and power (Jasanoff 2005), and the social and political dimensions of institutions and governance (cf. STEPS Working Papers 1–3).

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.

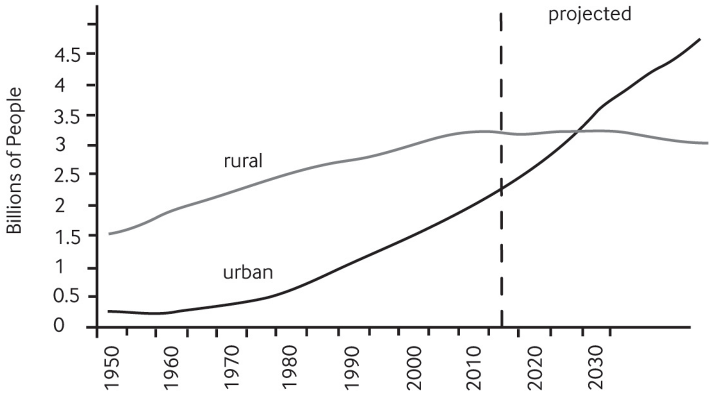
Thus, 'sustainable development' – and with it, 'sustainable agriculture' – is also only partly knowable and predictable (cf. STEPS Working Paper 1 on Dynamics). How it develops will depend on decisions and actions that have yet to be taken, and requires processes of reflexive deliberation at the centre 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? This section explores this question through an assessment of key drivers of change and their effects that characterise contemporary agri-food systems.

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 (Figure 1).

Figure 1. Rural and Urban Population Trends



Source: UN World Population Prospects 2005

The contribution of agriculture to livelihoods is evident from the fact that 70 percent of the world's poor people, including the poorest of the poor, and 75 percent of the world's malnourished live in rural areas, where most of them are involved in agriculture. The Millennium Development Goal of halving extreme poverty and hunger will not be met without reducing this rural poverty (UN Millennium Project 2005a). Meeting this food security goal will be a major challenge. Yet rural poverty remains stubbornly high, even with rapid growth in the rest of the economy. Rural-urban income gaps tend to rise as non-agricultural growth accelerates, creating major social tensions as expectations for better lives remain unfulfilled for a majority of the rural people (Tacoli 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. Of course, predictions of food security outcomes have been a part of the policy discourse in agriculture at least since the Reverend Thomas Malthus wrote *An Essay on the Principle of Population* in 1798 (Malthus 2003). Over the past several decades, some neo-Malthusians or 'catastrophists' have expressed concern about the ability of agricultural production to keep pace with global food demands (cf. Brown and Kane 1994; Meadows, et al., 1992; Ehrlich and Ehrlich 1990), whereas other 'cornucopians' have forecast that technological advances or expansions of cultivated area would boost production sufficiently to meet rising demands (cf. Conway and Toenniessen 2003; Evans 1998; Simon 1998; Boserup 1965; Smil 2000). Thus far, dire predictions of a global food security catastrophe have proved unfounded, in the sense that aggregate food supply has kept pace with population growth, although hundreds of millions remain hungry and malnourished.

Nevertheless, despite the fact that food production per capita has been increasing globally, major distributional inequalities remain, linked primarily to poverty (Thompson 2003; Drèze and Sen 1989). Global food production has increased by well over 130 percent since the 1960s, yet the fact that almost 78 per cent of countries that report child malnutrition are food-exporting countries dramatically illustrates a 'paradox of plenty' (Mittal 2006). Moreover, the productivity of major cereals appears to be reaching biological limits in some regions, despite heavy use of agrochemical inputs, and consequently production is now growing more slowly than in recent decades. Widespread and persistent hunger is a fundamental contradiction in today's world when production and productivity in agriculture have grown faster than effective demand. An estimated 852 million people were undernourished in 2000–02, up 37 million from the period 1997–99. Of this total, more than 95 percent live in developing countries (World Bank 2006). Sub-Saharan Africa, the region with the largest share of undernourished people, is also the place where per capita food production has lagged the most. This underperformance of the agriculture sector has been exacerbated by ethnic conflict and political instability, declining terms of trade, dwindling investments in agricultural research and infrastructure and increasing water scarcity.

The challenges faced today are, however, substantially different from those encountered by the Green Revolution producers who achieved sustained gains in agriculture productivity only a few decades ago. 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 2007; Reardon, et al 2003; Reardon and Barrett 2000).

A major concern about this concentration is the control exercised by a handful of private corporations over decision-making throughout the agri-food system. In the past, most of the global trading and grain-handling firms were family-held operations which operated in one or two stages of the food system and in a very few commodities. Consequently, risk exposure of many rural households to market forces was very different from that today. Risks were often reduced by the state through government-controlled marketing boards and similar parastatal organisations, which assured a price structure, input and output markets and access to improved technologies and training. Public investments in research and development (R&D) resulted in higher yielding farm systems. Furthermore, innovations were encouraged through public subsidies of one kind or another. In much of Asia and Latin America these innovations led many farm households to shift to more productive and higher return farming systems (World Bank 2005).

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). As agriculture becomes more concentrated and integrated, these giant clusters are establishing an oligopsony – a market in which a small number of buyers exerts power over a large number of sellers – over large parts of the agri-food chain, enabling them to maximise profit while minimising risk. As a result, the food system has begun to resemble an hourglass. At the bottom are millions of farmers and farm labourers producing the food and fibre, while at the top are billions of consumers, both rich and poor. At the narrow point in the middle are the dozen or so multinational corporations – the input suppliers, food processors and retailers – earning a profit from every transaction (Vorley 2003). Typically, goods are exchanged through closed contracts or intra-firm transfers rather than open wholesale markets (Reardon, et al. 2003; Stumo 2000) and even when they are exchanged in wholesale markets, prices may be well below the cost of production due to oversupply (Reardon and Berdegué 2002). Consequently, the 'cost-price squeeze' falls on the producers, who bear the bulk of the risk and share little, if any, of the rewards.

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 USD $279 billion (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 still protect 28 percent of OECD's agricultural production (a figure that is probably underestimated) (cf. de Gorter and Hranaiova 2004). Although the average tariff on agricultural products is reported to be 10-20 percent, extremely high tariffs (up to 500 percent) on specific agricultural imports are reducing market opportunities for developing country farmers. Moreover, escalating tariff structures, which place higher tariffs on more processed products, are widespread. These tariffs protect processing industries in industrialised countries and amount to a tax on development, because they limit developing countries to producing low value-added primary products (Ingco and Nash 2004).

Global and regional economic integration is accompanied by other challenges that further weaken the socioeconomic 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 (Edstrom, et al. 2007; UNAIDS 2006). Global environmental change is increasing pressure on an already fragile natural resource base in complex, risk-prone environments that are the mainstay of rural livelihoods (Erickson 2006a; Tilman, et al. 2001). 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).

This is not helped by the fact that attention to agriculture in terms of policy commitments and investment levels declined in both international donor and developing country policies and programmes (Bezemer and Headey 2006), 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 forms unsuited to development and broad-based diffusion of poverty-reducing innovations (Byerlee and Alex 1998). Investments in science and technology have been shown to pay off most strongly for countries and regions with highly integrated technical and economic systems able to diffuse and apply results of new research (UN Millennium Project 2005b; Hazell and Haddad 2001). Constraints faced in mobilising public resources for agricultural development in countries with widespread poverty and under-nourishment are illustrated by relating government expenditure on agriculture to the size of the agricultural labour force. In countries where more than 35 percent of the people are undernourished, government expenditure per agricultural worker averages

USD $14 or 50 times less than the USD $880 in countries with the lowest rates of under-nourishment (FAO, IFAD and WFP 2002).

Similar problems also affect agricultural R&D. Corporate R&D agendas understandably focus on potentially profitable sectors, which frequently do not include poor people. Only in the public and charitable sectors have agricultural R&D policies engaged with the needs of the rural poor.

Assumptions about the vulnerability and/or robustness and resilience of agricultural systems remain contested. Many studies predict that world food supplies may not necessarily be adversely affected by moderate climate change, but only by assuming farmers will take adequate steps to adapt to climate change and that in some regions additional CO_2 will contribute positively to increased yields (IPCC 2007). Many developing countries are likely to fare badly, however, as climate change may result in unpredictable growing conditions, including more intense rainfall events between prolonged dry periods, as well as reduced or more variable water resources for irrigation in tropical environments (Fischer, et al. 2002; Tilman, et al. 2001). Increasing agricultural expansion into marginal lands and forests may in turn put these areas at greater risk of environmental degradation. Such conditions may promote pests and disease on crops and livestock and increase the incidence of vector-borne diseases in humans (Sutherst 2004), as well as increase soil erosion and desertification (Montgomery 2007).

The HIV/AIDS pandemic is another relevant concern for the sustainability of agriculture. More than 28 million people have died since the first case was reported in 1981. In 2005, AIDS killed 2.8 million people, and an estimated 4.1 million became infected, bringing to 38.6 million the number of people living with the virus around the world. Of this total, 24.5 million of these people live in Sub-Saharan Africa (where in some countries one in three adults are infected) and 8.3 million live in Asia (UNAIDS 2006). In addition to its direct health, economic and social impacts, the disease also affects food security and nutrition. Adult labour is often reduced or removed entirely from affected households, and those households then have less capacity to produce or buy food, as assets are often depleted for medical and/or funeral costs (Edstrom, et al. 2007; Gillespie 2006). The agricultural knowledge-base often deteriorates as individuals with farming experience and scientific knowledge succumb to the disease.

Moreover, agri-food systems are changing in many ways as a result of the dynamic interactions of a range of environmental and socio-economic drivers, including global environmental change, agricultural intensification, concentration of production, vertical integration and coordination, industrialisation, deregulation and economic liberalisation and urbanisation. Appendix 1 sets out some of the main patterns and processes of change in the global agri-food systems, and shows how these dynamic changes are resulting in fundamental transformations of these systems, both in terms of their activities and outcomes.

4. CHARACTERISTICS OF AGRI-FOOD SYSTEMS

Agriculture therefore has a number of features that distinguish it from other productive sectors. Among other things, it is mainly a private activity implemented locally mostly by households, but it also has many dimensions of collective action, is deeply affected by global forces and depends greatly on public interventions for its structure, its support and its development. Taking into account these drivers of change, what are the key characteristics of agri-food systems that demand attention? The following, we suggest, are critical:

- **The dynamics of production**. Agriculture is characterised by high dependency on natural resources, spatial dispersion of activity, seasonal variables, asymmetries in information due to location and distance, high risks associated with the vagaries of nature, and difficulties in sustaining the productivity of natural resources, because their use and reproduction typically conflict.

- **Integrated agri-food systems**. Market developments, technological progress, institutional changes and policy interventions in one part of the world have far-reaching implications, even for distant actors, as global and regional supply chains link producers and consumers in different parts of the world

- **Market failures**. Failures of input and output markets for agricultural goods and services are associated with high transactions costs, particularly adversely affecting poor farmers, information asymmetries, incomplete property rights, externalities and missing actors. These affect access to markets, the availability of insurance and financial services, and the underwriting of contracts.

- **Public sector interventions**. There is a significant need for public sector interventions to compensate for these market failures. This makes agriculture highly vulnerable to extractive policies (cheap food policies), land grabbing, rent seeking, regressive subsidies and exposure to corrupt officials. Public budgets in agriculture can easily be prey to clientelism and elite capture, major causes for the mis-investment of already undersized public budgets. Equally, they can be distorted and misdirected through the changing whims and misguided policy prescriptions of international donors. Consequently, the political economy of policy and investment in agriculture can determine success or failure in agricultural development.

- **Socio-cultural systems**. The close correspondence between agriculture as a productive activity ('agri-') and rurality as a way of life ('-culture') (Cernea and Kassam 2006; Pretty 2002) make social relations in rural society important determinants of access to resources (for example through land rental markets), asymmetries in power (including by gender and ethnicity) and benefits from public services. These affect dynamic poverty outcomes in agriculture.

- **Heterogeneity and diversity**. Actors with better asset endowments in favourable areas can take advantage of new markets and of new technological and institutional opportunities. In contrast, large segments of the smallholder population remain reliant on subsistence-oriented activities, linked to labour markets as net sellers and to food markets as net buyers, but relying on agriculture for home consumption and as a safety net of last resort.

- **Collective action**. Effective forms of cooperation and collective action are essential for the millions of smallholders, pastoralists, fisher folk and farmworkers to have their voices heard in key regional and national policy forums. They are also essential to enable producers' associations and federations achieve economies of scale (meeting new market requirements (e.g. grades and standards) and interacting in local clusters of economic activity), access public services and manage common property resources (Rondot, et al 2004).

The key question – addressed in a preliminary way by this paper and the wider work on food and agriculture by the STEPS Centre – is: how, in the face of these old and new challenges, can poor, marginal people negotiate pathways to Sustainability through agriculture? This paper therefore provides an assessment of how different visions of agricultural development, underpinned by contrasting narratives of technological and economic change, respond to these challenges. Yet, despite the diversity of drivers and contexts, the complexity of dynamics and the uncertainties that prevail, current debates about agricultural change in developing countries are often couched – implicitly, if not explicitly

– in terms of notions of 'progress' towards a singular goal. Frequently, the underlying assumption is that such progress is achieved through the transfer of knowledge, ideas, models, practices and technologies from the 'developed' world to the 'developing' world, or from 'modern' science to 'backward' farming settings. For example, in the early 1990s some Indian agricultural universities based their curriculum on 20-year old textbooks from the United States, as if no new, locally-specific innovations had happened in the intervening years (Chambers pers comm. 2007). Within this framing are often embedded notions about how agricultural development occurs in a linear sequence of stages – from 'backward' to 'modern', from 'old' to 'new', from 'under-developed' to progressively more 'developed', from pre-industrial to industrial (Scoones, et al., 2005). Thus, there is often assumed to be a singular path to progress, and to be committed to this path governments, farmers, aid agencies and analysis have to be uniformly and unquestioningly 'pro-innovation', 'pro-technology' and 'pro-development'.

Those who criticise this monolithic linear assumption are sometimes accused of being 'anti-technology' or 'anti-modernity'. Our approach is not hostile to beneficial technological changes, but we do reject approaches that assume that there is one, and only one, technological trajectory that implicitly denies the existence and benefits of alternative pathways, or even multiple pathways, towards a broader goal of poverty reduction, social justice and environmental sustainability. Thus, in considering possible pathways towards this goal, we assume that there may be multiple routes to improving the relationship between complex food system and poor people in developing countries, and that poor rural people often have relevant agricultural knowledge.

DIVERSE RURAL WORLDS

Acknowledging uncertainties, embracing diversity and interacting with dynamic systems over time means that these pathways are frequently in a state of flux, and may work for some people and practices in some places, but not in others. Which pathways are chosen, and with what results is of course a wider, ultimately political, choice – discussed in STEPS Working Paper 2 on Governance – but when making that change it is important to take into account underlying dynamic conditions in particular contexts. Such an approach will need to address the specific needs of people inhabiting different 'rural worlds' (OECD 2006; Pimbert, et al. 2003; Vorley 2002).

Most rural areas are characterised by a highly diverse range of stakeholders involved with agriculture, with considerable variation in their assets and access to markets and the ways institutions promote or constrain their interests and opportunities (Thompson 2006). Many, for example, are not full-time farmers, mixing agricultural activities with other rural, non-farm income sources. To address the needs of the rural poor, agricultural science and technology policy needs to engage with such complex, dynamic settings. From the diverse potential pathways available, which are sustainable in terms of the needs and priorities of local people? Which socio-technical systems will assist which people in what ways? How does this feed into processes of priority setting in agricultural research and development? And what wider innovation systems – involving not only upstream science, but also market, institutional and policy configurations – make sense? These are just some of the – very large – questions that attention to dynamic agri-food systems reveals. These, in turn, highlight how a holistic understanding of the role of agriculture in rural economies and in people's livelihood strategies is an essential starting point.

A typology of 'Five Rural Worlds' can help inform our understanding of the dynamics of diverse and complex agri-food systems and livelihood strategies, and the potential pathways that may be open to them (or closed) (Box 1). These rural world categories are of course not mutually exclusive. The typology is used here as a guide rather than a rigid framework for differentiating rural households. It is limited in its ability to represent intra-household difference and gendered pathways, which can be quite divergent (cf. Guijt and Shah 1998). Moreover, it focuses primarily on the production side of agriculture and neglects the consumption part of agri-food systems. However, by using this more differentiated analysis based on rural people's livelihoods, it makes clear that poverty is located unevenly across and within rural populations, that policy in and for food and agriculture affects different groups in different ways and that the actions of one rural group can improve or impair the livelihoods of others. In other words, any analysis must be explicitly integrative, and examine trade-offs between options and pathways.

Box 1. Understanding Complexity and Diversity: Five 'Rural Worlds'

Rural World 1 households and enterprises engaged in high-value, export-oriented agriculture, make up a very small minority of rural households and firms in the developing world. In addition to their land and other holdings, producers and firms in this category have direct access to finance, risk management instruments, information and infrastructure necessary to remain competitive in their business operations. Most have an influential voice in national policies and institutions affecting their enterprises and, perhaps even more important, close ties to buyer-driven value chains associated with global agriculture.

Rural World 2 accounts for a substantial number of rural households and agricultural firms in the developing world. The one word that most aptly characterises them is 'traditional'. They are frequently part of the local elite but have little influence at the national level. They have sizable landholdings often devoted to both commercial and subsistence agriculture. They previously had access to basic services, such as finance, but with the advent of liberalisation and the consequent withdrawal of the state from a direct role in agriculture, the availability of these services declined rapidly.

Rural World 3 households – fisherman, pastoralists, smallholders and associated micro-enterprises – are survivalist. Food security is their main concern, and their small production units are almost totally dedicated to home consumption. Their assets are poorly developed, and they have very limited access to key services (e.g. credit) that would enable them to increase the returns to their assets.

Rural World 4 households are landless or near-landless, frequently headed by women, with little access to productive resources other than their own labour. Sharecropping or working as agricultural labourers for better-off households in their communities in Rural Worlds 1, 2 and 3 is perhaps the most secure livelihood option for many of them. For others, migrating to economic centres on a daily, seasonal or even permanent basis is their best hope for survival. But their low education levels are a major barrier to migrating out of poverty.

Rural World 5 households are chronically poor. Most have sold off or been stripped of their asset holdings during periods of crisis. Remittances from relatives, community safety nets and government transfers are vital to their sustenance. As a result of the HIV/AIDS pandemic, many more households are facing this precarious situation, particularly in Africa. Entrenched gender inequalities exacerbate this problem. Social exclusion often typifies the relationship of Rural World 5 to the larger community. Social protection programmes, including cash and in-kind transfer schemes, will be critical for this group for some time.

Sources: OECD 2006; Pimbert, et al. 2003; Vorley 2002.

Responding to complexity and uncertainty are essential elements in sustainable agri-food systems, perhaps the riskiest sector in the economy, which are not only subject to the price volatility facing many sectors, but also highly dependent on nature and weather, leaving them vulnerable to droughts and floods, pests and diseases, and other shocks and stresses. These vary in their nature and have different impacts across the different rural worlds, and change with the seasons (Chambers, et al. 1981). For example, volatile international markets directly affect Rural World 1 producers and ultimately their need to employ farm workers from Rural Worlds 3 and 4. Generic shocks and stresses such as those associated with global environmental change can shift farm households in Rural Worlds 2 and 3 either above or below the thresholds of profit and food security. For agricultural households to have more secure and prosperous livelihoods, therefore, they need more ability to respond to and uncertainty and address attendant vulnerabilities (OECD 2006; Pimbert, et al. 2003; Vorley 2002).

Without strengthening the capability of poor rural households to cope with complexity and uncertainty they are exposed to, they will be reluctant to and innovate and may remain trapped in low-risk and low-yielding livelihood strategies (Barrett and Swallow 2004). Strengthening poor rural households to create more resilient and robust food systems and remain active and productive agriculturalists despite experiencing shocks and stresses of different kinds and magnitudes is a key challenge for agricultural development (Thompson 2006).

5. DOMINANT NARRATIVES OF AGRICULTURAL SCIENCE AND POLICY: TECHNOLOGY AND GROWTH

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? This section examines two intersecting perspectives – centred on technology/production and economic growth – which have dominated policy discourse on agricultural development. Over the past sixty years or so, these two narratives have come to shape the dominant policy discourses in agricultural development, each with deeply rooted historical precedents. Both have invoked crises in debates about global and regional agri-food systems, drawing on different sources for scientific legitimacy and calling for and in turn receiving impressive international responses through the international aid machinery. In presenting an overarching narrative of progress through modernisation and growth, they suggest a particular (set of) pathway(s) for development. But they also raise some important questions: how do these long-dominant perspectives frame and structure debates and, in so doing, include and exclude different perspectives? How do they respond to the challenges of dynamic change and complexity? And how do they frame debates about sustainability?

This section tackles these questions with a look at how these two mainstream perspectives have emerged historically. While there have been numerous variations on these two themes – technological change and economic growth – over the past decades they have remained the deeply embedded core narratives framing agri-food policy. While the discourse has shifted slightly in technological terms, from the 'Green Revolution' to the 'Gene Revolution' or 'New Green Revolution' (cf. Rockefeller 2006), and in economic terms, from the 'old agriculture' to the 'new agriculture', they persist as equilibrium-centred guiding narratives, portraying technological change in a linear fashion. In this section, then, we examine the history of these framings and their influence on agricultural science and policy over the latter half of the 20th century and highlight how they continue to shape the current debates on the future of agri-food systems in the 21st century.

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.[1] The term Agricultural Revolution has also been applied to agricultural changes in other parts of the world, notably France (Dyson 1996). In England, output increased through the intensification of land use, while land productivity increased through diffusion of mixed farming systems which incorporated fodder crops into arable 'four-field' rotation systems. Clover and other legumes (e.g. peas and beans) were particularly important since they converted atmospheric nitrogen into soil nitrogen and thus made a net addition to the supply of the most important nutrient for arable crops (Smil 2004). Labour productivity also rose at an unprecedented rate, but there is no obvious technological explanation for this before the mid-19th century and probably had more to do with associated institutional changes, notably the Inclosure Acts (Kerridge 1992, 1967; Allen 1991; Wordie 1983; Jones 1974). In France, in the 18th and 19th centuries, the amount of land that was farmed was determined by how much could be harvested by one person with a scythe. From the mid-19th century the introduction of machines for harvesting and threshing grain improved labour productivity dramatically.

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 from one billion in the mid-18th century to two billion by the middle of the 19th century. Traditional farming relied on a combination of increasingly intensive recycling of organic wastes and culti-

[1] Though some authors argue that England's agricultural revolution took place earlier (cf. Allen 1991; Jones 1974).

vation of leguminous crops, but these inputs were insufficient to sustain high crop yields over large cultivated areas. As the concerns about future nitrogen intensified during the latter half of the 19th century, chemists tried to prepare ammonia, the simplest of all nitrogen compounds, from its elements (Smil 2004; 2000). Concerns grew once again that a burgeoning population would be plunged into Malthusian disaster and significant efforts were made to apply science to develop new technologies to boost agricultural productivity.

According to this production-focused framing of agricultural change, salvation came with the development of the 'Haber-Bosch process' in which atmospheric nitrogen was fixed and used to manufacture ammonia fertiliser. Beyond the landmark development of synthetic fertilisers, the 20th century has also been widely viewed as an era of plant breeding and, more recently, molecular genetics (Leigh 2004; Smil 2004). The introduction of the concept of 'hybrid vigour' by Schull in 1900 stabilised U.S. maize production (Trewavas 2001). For the first time the genetic base of crop production could be controlled and easily adjusted to accommodate the differing agro-ecological conditions found in the continental United States. This new technology was soon to spread other parts of the industrialised world and, eventually, to developing countries through an unprecedented global effort to meeting the perceived threat of rising population and global food demands.

THE GREEN REVOLUTION

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). The term 'Green Revolution' was first used in 1968 in a speech by William Gaud, the former Administrator of the U.S. Agency for International Development, who stated:

> Record yields, harvests of unprecedented size and crops now in the ground demonstrate that throughout much the developing world – and particularly in Asia – we are on the verge of an agricultural revolution....These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violent Red Revolution like that of the Soviets, nor is it a White Revolution like that of the Shah of Iran. I call it the Green Revolution (Gaud 1968).

Implicit in Gaud's statement and the underlying rationale of the architects of the Green Revolution, both the philanthropists who funded it and the plant breeders who made it possible, was what John Perkins (2003) has termed the 'Population-National Security Theory'. This assumed that population growth led in a Malthusian fashion to hunger, which, in turn, could lead to social unrest, providing opportunities for the growth of communism (i.e. Gaud's 'Red Revolution'). Thus, in order to understand the origins and genesis of the Green Revolution, the global effort to develop HYVs must be located in this earlier geopolitical landscape of the Cold War, which embraced a Malthusian view of food shortages in the post-1945 period and the recognition that the Green Revolution could be used as a key instrument of US foreign policy (Cullather 2004; Perkins 2003; Dowie 2001; Thompson 1992).

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 Mendellian genetics, applied plant breeding (led by the UK and the US), the ability to manufacture and market inexpensive nitrogen fertiliser (cf. Smil 2004), and the controlled supply of water through irrigation technologies.

In the first phase of the Green Revolution, rice and wheat were the primary crops and Mexico, India and the Philippines were its crucibles. The International Rice Research Institute (IRRI) was founded near Manila in 1960 and the Center for Maize and Wheat Improvement (CIMMYT) in Mexico in 1963. What began in the 1940s under the auspices of the Rockefeller Foundation focused on improving wheat has grown in half a century to a massive multi-billion dollar network of 15 international agricultural research centres – the Consultative Group of International Agricultural Research (CGIAR) and dealing with virtually all major food complexes in over 100 countries (Yoxen 1983). This research programme for HYVs has brought together in university-type research centres transnational groups of scientists which conducted sophisticated breeding programmes. IRRI, for example, built upon rice breeding expertise and dwarf varieties from China, Japan and Taiwan to produce, through hybridisation, new dwarf HYVs which were resistant to lodging, sensitive to nitrogen fertilisers and which could be double or triple cropped through a shortening of the growing season. Similar achievements were made for wheat after Norman Borlaug (later awarded the Nobel Peace Prize for his work) crossed Japanese semi-dwarf varieties with Mexican wheats at CIMMYT in Mexico. High-yielding varieties have since been developed by the CGIAR for other major food crops important to developing countries, including sorghum, millet, maize, cassava and beans. Through the 1970s and 1980s, the diffusion of these hybrid planting materials and associated technologies (pumpsets, small tractors, etc.) included a central role for the state. This typically involved new subsidies, credit, extension services, irrigation infrastructure development and national breeding programmes. A hallmark of the Green Revolution was that land productivity increased faster than labour productivity as a result of the new technological packages, thus increasing employment and wages, and that total factor productivity in agriculture increased faster than the fall in food prices, so both poor producers and consumers benefited (Hazell and Ramasamy 1991; Lipton with Longhurst 1989).

Since the 1990s, this approach has given way to a much stronger emphasis on private sector provision of these services in many countries – both private companies and NGOs – but the mix of technologies remains remarkably similar. Today, HYVs are grown worldwide – including roughly 95 percent of the rice in China and Korea, and 70 percent 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 with Longhurst 1989). But there has been considerable disagreement over the productivity increases attributed to Green Revolution HYVs. In one of the best known and earliest reviews, Keith Griffin (1974) painted a bleak picture of the effects of HYVs between 1970 and 1974, arguing that there had been no Green Revolution in rice. A subsequent assessment by Michael Lipton with Richard Longhurst (1989) showed that the output increases in wheat and maize were indeed dramatic (at least 4 per cent per year) and that those in rice were slower, but no less substantial overall. Lipton and Longhurst pointed out, however, that there were significant regional differences, with Africa missing out on balance, and that there were major problems of equity within countries which reflected disparities in irrigation development and water control investment.

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. In the early years, the adoption of Green Revolution 'packages' – and the recognition that these were not in practice scale neutral (i.e. that they favoured larger, resource-rich farmers) – prompted much analysis of new forms of social differentiation among peasantries, of conflict between 'adopters' and 'non-adopters', and of deteriorating labour conditions as HYVs were labour-displacing rather than labour-saving. There was no simple polarisation of landholding in places like India and Philippines, though there has been the consolidation of a class of increasingly commercialised and organised rich farmers who benefited from adoption of the new technologies. These growing social differences inspired farmers' movements in many countries and influenced key agricultural policy agendas. The impact on labour markets (new forms of migration, changing forms of tenancy, etc.), on land tenure arrangements and on social inequality is enormously complex in part because of the linkages between on-farm productivity increases and off-farm employment opportunities (Davis, et al. 2002; Hazell and Ramasamy 1991). Amplified inequalities have often emerged, but this has often been attributed by the proponents of the Green Revolution to population pressures and state rent-seeking rather than to technology-driven agricultural change as such. All of these direct and indirect consequences have sparked a debate over the consequences of HYVs, and new agricultural technologies more generally, which continues to the present.

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). The first issue turns less on output than on availability and 'entitlements' – in short, the social component of the revolution. The second refers to the problems of both the uneven adoption of HYVs and the inherent biases built into the technology packages themselves. The 'miracle seeds' and associated technologies are often not 'pro-poor' and do not address the needs of land-poor and landless producers, as there was little appreciation of the complexity and diversity of either farmers' physical or social environments. Thus, it should come as no surprise that in India, one of the heartlands of the Green Revolution, the poorest 30 percent of the population (some 285 million people) saw virtually no increase in their low cereal and nutrient intakes over the last 25 years of the 20th century (Rao and Radhakrishna 1999).

Furthermore, the revolution brought with it a wide array of environmental problems. Vast expanses of 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. Thus, today four once-rare plants (maize, rice, wheat and barley) have become the dominant plants on earth as humans have become the dominant animal. Indeed, these four annual grasses now occupy roughly 40 percent of global cropland (Tilman, et al. 2001; Tilman 1999).

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.[2] 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).

---

[2] 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. The primary goal of the Alliance is to 'increase the productivity and profitability of small-scale farming using technological, policy and institutional innovations that are environmentally and economically sustainable'. The Program for a Green Revolution in Africa (ProGRA) is a supporting organisation that is being administered under the aegis of AGRA. The first initiative of ProGRA is the Program for Africa's Seed Systems (PASS). It began in 2006 and will be funded with a total of $150 million over a five-year period. It has four main components which its sponsors claim will provide an integrated approach to the scientific, educational, economic and policy aspects of building seed systems in Africa: (1) Education for African Crop Improvement; (2) Fund for the Improvement and Adoption of African Crops; (3) the Seed Production for Africa Initiative; and (4) the Agro-Dealer Development Program. For details, see the official Rockefeller Foundation website: http://www.rockfound.org/initiatives/agra/agra.shtml. There have been a number of recent critiques of AGRA, including one by three leading agroecologists linked to the Center for Food and Development Policy (Food First) (Holt-Gimenez, et al. 2006) - http://www.foodfirst.org/files/pdf/policybriefs/pb12.pdf - and another by GRAIN (2006) the international agrobiodiversity NGO - http://www.grain.org/articles_files/atg-7-en.pdf.

THE GROWTH NARRATIVE

A second, equally powerful narrative of agricultural change emerged in some of the post-war development literature in the 1940s and has increased in popularity ever since. This has subsequently focused 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 2007, 2005; 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.

In the early 1950s, most development economists believed the agricultural sector had little to contribute to economic development. Classical theorists, led by Arthur Lewis (1954), viewed economic development as a growth process of relocating factors of production, especially labour, from an agricultural sector characterised by low productivity and the use of traditional technology to a modern industrial sector with higher productivity. The contribution of agriculture to economic development was seen as limited and diminishing. Agriculture acted more as a source of food, fibre and labour than a source of economic growth. Although marginal, agricultural growth was still viewed by most analysts as necessary for successful economic transformation for two reasons: (1) to ensure the supply of food and prevent rising food prices and real wages from undermining industrial development; and (2) to utilise a major natural resource (i.e. land) as an additional 'free' source of growth that would not compete with resources for industrial growth. Nonetheless, Lewis's theory was invoked to support the industrialisation-led strategies adopted by many developing countries during the 1950s and 1960s. Indeed, 'development' was generally equated with a decline in agriculture's share of both national income and employment. The aim of development policy was to enhance the transfer of resources from traditional agriculture to the industrial sector. An additional role of agriculture was to provide the rising urban population with adequate food at reasonable prices, thereby curtailing inflationary pressure and reducing any risk of political uprisings (e.g. 'food riots').

Beginning in the early 1960s, however, a major revision in development thinking argued for a central role for agriculture as a driver of growth, especially in the early stages of industrialisation. In 1961, Bruce Johnston and John Mellor wrote an influential article entitled 'The Role of Agriculture in Economic Development', in which they argued that agriculture can serve as a catalyst to economic growth (Johnston and Mellor 1961). They asserted that agriculture could make five important contributions to economic development. It could provide labour to the industrial sector; offer limited amounts of capital for the industrial sector; generate foreign exchange through trade of agricultural commodities; supply low-cost food to growing urban populations; and provide a significant market for both domestic and industrial goods and services (e.g. clothing, tools, machinery, etc.).

By emphasising expenditure linkages – especially through consumption – Johnston and Mellor's work 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 nonfarm 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 or Transfer of Technology (TOT) model to poor producers (Ruttan 1998).

In post-war development literature, peasant producers were often portrayed as obstacles to agricultural development, as they were seen to be bound by custom and tradition. In an iconoclastic work published in the mid-1960s, the economist Theodore W. Schultz (1964), who subsequently received the Nobel Prize in Economic Sciences, advanced a view of peasant producers as 'efficient but poor' (Abler and Sukhatme 2006). He viewed them as making efficient use of the resources at hand but living in societies in which productivity enhancing high-payoff inputs had not been made available to them. Schultz insisted that the principal source of growth in agricultural production in modern agriculture was reproducible resources. Although the services of nature, particularly land and water, would be essential for sustaining agricultural production, the sources of growth would be based on new knowledge and new technology. Schultz's point was that the root of rural poverty lay in the lack of profitable agricultural technologies and a lack of investment in the 'human capital' needed to cope with changing agricultural development (Klein and Cook 2006; Schultz 1968, 1961). Consequently he advocated greater investments in education and training to increase human capital and enhance agricultural development.

It was also in the mid-1960s that Arthur Mosher (1966) published *Getting Agriculture Moving: Essentials for Development and Modernization*, which was widely read in development circles and translated into numerous languages. He argued that there are five 'essentials' which must be available to farmers if agriculture is to develop and a further five 'accelerators' that will 'get agriculture moving.' Mosher's five 'essentials' are strikingly prescient, as they anticipated many of the main arguments made by proponents of 'pro-poor agricultural growth' today: (1) markets for farm products – with emphasis on the need for adequate infrastructure to move farm products to market, thereby cutting transaction costs, and the agro-enterprises to sustain a supply chain; (2) unceasing changes of technology – which highlights that by having access to and evaluating new and changing technologies, farmers learn to choose selectively to increase productivity and minimise risk; (3) local availability of supplies and equipment – which also depends on adequate infrastructure and enterprise development; (4) production incentives for farmers – this relates to favourable policies for the agricultural sector and fair prices for farm products; and (5) transportation – again linked to infrastructure and agribusiness development. To complement these 'essentials', Mosher called for five 'accelerators': (1) education for development; (2) production credit; (3) collective action by farmers; (4) improving and expanding agricultural land (through good husbandry and adoption of appropriate technologies); and (5) national planning for agricultural development, with emphasis on enlightened public policies that support the agricultural sector.

THEORY AND PRACTICE

Despite this call to 'get agriculture moving', the very opposite took place over the next two decades. 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).

In an attempt to counter those trends, the World Bank released its 1982 World Development Report, which addressed the role of agriculture for development. Its main observation was that impressive progress had been made as a result of the Green Revolution, but that those achievements had been uneven, bypassing significant parts of the world, particularly Africa. Its principal policy recommendations were to: remove the pervasive distortions in price incentives, because even smallholders are price-responsive; increase public and international investment in agricultural research, especially for Africa where it was lagging; and increase public investment in rural infrastructure, irrigation and education, in part relying on development assistance from multi-lateral agencies like the World Bank and donor countries (World Bank 1982). 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).

The structural reforms of the 1980s were pushed even harder by the so-called 'Washington Consensus' in the 1990s, which emerged as the dominant development paradigm. It emphasised economic growth through global trade and market liberalisation, with the role of the state reduced to providing the governance and regulatory environment to allow markets to work well, along with investments in core public goods. Agriculture did not feature centrally in the early Washington Consensus debates, however, and the main economic reforms either excluded the sector altogether or were implemented only partially (Kydd and Doward 2001).

A REVERSE SWING OF THE PENDULUM

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 forthcoming World Development Report for 2008 on agriculture for development, the Organisation for Economic Co-operation and Development (OECD) Poverty Network report on agriculture or DFID's recent agricultural policy paper, emphasis now is being placed on efforts to develop 'pro-poor' agriculture that is also 'pro-growth' (World Bank 2007, 2005; OECD 2006; DFID 2005; cf. Cabral and Scoones 2006 for a review). Hence, today the World Bank argues that the agenda set out in its *1982 World Development Report,* which focused on incentives, technology and public investment in agriculture, remains incomplete. For many poor countries, access to international agricultural markets is very problematic despite promotion of explore-led agricultural development policies. The suspension of the Doha development round of trade talks has inhibited the dismantling of protectionist tariff and trade policies which serve as barriers to entry to OECD markets for agricultural products from developing countries (Anderson, et al. 2006; Ingco and Nash 2004; Wade 2003). Technological gaps have also widened sharply for the poor (Pardey, et al. 2006). Furthermore, rural public investments in both infrastructure and social development remain hugely inadequate, especially in the agriculture-based countries (Bezemer and Headey 2006; Fan, et al. 2000). Thus, the World Bank believes completing this pro-poor agricultural growth agenda should be a priority for the international development community (World Bank 2007).

Similarly, in many developing regions, including Africa, many governments are increasingly highlighting agricultural growth. For example, Uganda has a strategy for agricultural modernisation, Kenya has launched a *Strategy for the Revitalisation of Agriculture* and Ethiopia has committed to a second *Poverty Reduction Strategy Paper* (PRSP) – the PASDEP or the *Plan for Accelerated and Sustained Development to End Poverty,* all of which are committed to a substantial push to accelerate agriculture-driven economic growth. Not since the 1960s and 1970s has the argument for a trickle-down approach to development, following on from growth and 'modernisation' in the productive sectors, been so dominant.

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 (cf. Poulton, et al. 2006; Almond and Hainsworth 2005; IFPRI, et al. 2005).

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. In Ethiopia, for example, the argument for focusing new PRSP investments on 'going for growth', with an emphasis on boosting commercial agriculture, is based on a series of SAM modelling inputs into the policy process. Necessarily, but perhaps problematically, these simplify the debate into one that considers just a few policy categories. For instance, in the case of the 2001-02 Babo Gaya SAM constructed by researchers at the International Food Policy Research Institute and associates, the agricultural economy for the nation as a whole is divided into 'subsistence crop farming', 'subsistence livestock farming' and 'commercial (or 'modern') crop farming' (Taffesse and Ferede 2004). By showing that what is (vaguely) defined as 'commercial' or 'modern' farming contributes a significant value-added share (so overall growth benefits) to the national economy, the study provides the empirical 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 (Teshome 2006).

Secondly, such discussion – reinforced by such models – is often wrapped up in another argument, that there is somehow a defined, uni-linear set of 'stages', 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, and that the challenge is to find the technology, institutional instruments and market incentives to push things from one stage to the next. This is central to the Johnston-Mellor-style growth argument discussed above and much academic and policy discussion since (cf. Dorward, et al. 2004; Eicher and Staatz 1998; Mellor 1995). But such stagist-evolutionist arguments about 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.

This is not to deny the need to generate growth and foster linkages between farm and non-farm, rural and urban worlds. Instead it provides an argument for understanding how in particular contexts, growth trajectories are different, and require different inputs, incentives and governance arrangements. Not all developing country farmers need to end up growing French beans or carnations through out-grower schemes for the European market, even if this is a good plan for some farmers in some places. There are other opportunities that need to be sought out, and the generalised models and universalised policy prescriptions do not help in the search for these pathways to sustainability, particularly in a period of rapid change and uncertainty.

6. ALTERNATIVE NARRATIVES: CHALLENGES TO THE DOMINANT PERSPECTIVE?

Despite the dominance of the Production-Innovation and Growth perspectives, there are a number of well-documented alternative narratives to mainstream agriculture that have emerged over the past two decades. We have selected two of the most prominent alternatives, as they have attracted substantial attention in key policy and scientific circles and represent separate, but complementary intellectual and philosophical traditions. The first of these may be broadly termed 'Agroecological', while the second may be described as 'Participatory'.

Both alternative visions seek to understand the dynamic nature of agri-food systems. Thus, they are necessarily interdisciplinary and synthetic in nature, historically situated (seeking to understand socio-ecological interactions in place-based context), and emphasise the development and application of integrated approaches that build on local knowledge and skills. Moreover, both stress the democratisation of agricultural research and development, support diverse forms of co-inquiry and co-management, and promote people-centred learning and action to foster change. Consequently, they do not take complex ecological and socio-economic issues and socio-ecological interactions in agriculture for granted, or focus on some narrow aspects of them by creating a science of the parts. Instead, they problematise them and, by so doing, embrace complexity and diversity – potentially supporting multiple pathways to sustainability. However, there are also clear limits to such approaches. Questions are raised, in particular, about the capacity to scale up such initiatives to meet the challenges of agri-food systems globally. This section, then, explores these two alternative perspectives, assessing the degree to which they meet the challenges of sustainability discussed in the previous section.

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; Francis, et al. 2003; 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.

In essence, the behaviour of agroecosystems depends on the interactions between the various biotic and abiotic components. By assembling a functional biodiversity it is possible to initiate synergisms, which support agroecosystem processes by providing ecological services such as the activation of soil biology, the recycling of nutrients, the enhancement of beneficial arthropods, and so on (Uphoff, et al. 2006). 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 2007, 1985).

Rather than depend on exogenous inputs, as in Green Revolution agriculture, agroecological practices mobilise as much as possible endogenous biological processes and potentials that are located within existing plant, animal and microbial genomes and that can be elicited from interactions among these diverse organisms and within and between their communities. With this in mind, the basic components of sustainable agroecosystems involve: vegetative cover as an effective soil- and water-conserving measure, met through the use of no-till practices, mulch farming, use of cover crops, etc.; the regular addition of organic matter (manure, compost and the promotion of soil biotic activity); nutrient recycling mechanisms through the use of crop rotations, crop/livestock systems based on legumes, etc.; pest regulation assured through enhanced activity of biological control agents, achieved by introducing and/or conserving natural enemies; and the restoration of diversity to the system through intercropping, rotations, agroforestry and the integration of crops and livestock (Uphoff, et al. 2006; Altieri 2002; Carrol, et al. 1990).

Generally, agroecological production focuses and manages resources in more intensive, smaller-scale operations that are more resource-efficient than extensive, large-scale production units. Many of the economic advantages that larger farms currently enjoy come more from economies of size than from true economies of scale. Thus, the commonly-found higher productivity per unit area on smaller farms is due in part to the greater diversity and integration found in small farm agriculture, as well as to the larger proportion of their land that small farmers actually plant and the greater amount of labour that they apply per unit area. This means that their lack of profitability derives more from their lack of market (bargaining) power than from true factor-use efficiency (Uphoff 2007).

As Miguel Altieri (2004: 14), one of the leading advocates of agroecology, has observed:

> ...a key challenge for agroecologists is to translate general ecological principles and natural resource management concepts into practical advice directly relevant to the needs and circumstances of smallholders. The strategy must be applicable under the highly heterogeneous and diverse conditions in which smallholders live, it must be environmentally sustainable and based on the use of local resources and indigenous knowledge. The emphasis should be on optimizing the productivity of complex systems at the field or watershed level, rather than the yield of specific commodities.

In addition to a focus on integrated biological processes, current trends among promoters 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). Rural people's knowledge about agroecosystems usually results in multidimensional, productive land use strategies, which generate, within certain ecological and technical limits, the food self-sufficiency of communities in particular regions. In this respect, agroecology may be defined as the 'ecology of sustainable food systems' (Gliessman 2006).

By understanding ecological features of agriculture, such as the ability to bear risk, production efficiencies of symbiotic crop mixtures, recycling of materials, reliance on local resources and germplasm, exploitation of full range of micro-environments, it is possible to obtain important information that may be used for developing appropriate agricultural technologies and innovations tailored to the needs, preferences and resource base of specific farmer groups and regional agri-food systems. But agroecosystems are also part of wider socio-ecological systems, too. Thus, there is a growing recognition, informed by feminist political ecology, that they have co-evolved with and are suited to particular social relations (e.g. gender, labour, etc.), which are suited to specific social as well as ecological contexts, although sometimes embodying inequalities and resource differentials, too (Rocheleau, et al. 1996).

RESOURCE-CONSERVING TECHNOLOGIES

There are a wide array of resource-conserving technologies and practices associated with these Agroecological Alternatives. Advocates argue, however, that what is important is not to focus on particular technologies or practices, but on an assemblage of technologies and associated management practices that incorporate crop diversity, legumes-based rotations, the integration of animals, recycling, and the use of biomass and residue management. Some of the most common integrated approaches include:

- Integrated pest management (IPM), which uses ecosystem resilience and diversity for pest, disease, and weed control, and seeks only to use pesticides when other options are ineffective
- Integrated nutrient management (INM), which seeks both to balance the need to fix nitrogen within farm systems with the need to import inorganic and organic sources of nutrients, and to reduce nutrient losses through erosion control
- Conservation tillage, which reduces the amount of tillage, sometimes to zero, so that soil can be conserved and available moisture used more efficiently
- Agroforestry, which incorporates multifunctional trees into agricultural systems, and collective management of nearby forest resources
- Aquaculture, which incorporates fish, shrimps, and other aquatic resources into farm systems, such as into irrigated rice fields and fish ponds, and so leads to increases in protein production
- Water harvesting, which can mean formerly abandoned and degraded lands can be cultivated, and additional crops can be grown on small patches of irrigated land owing to better rainwater retention
- System of rice intensification, which seeks to increase the productivity of irrigated and upland rice by improving the management of plants, soil, water and nutrients, which contribute to both healthier soil and plants supported by greater root growth and the nurturing of soil microbial abundance and diversity
- Livestock integration into farming systems, such as dairy cattle and poultry, including using zero-grazing.

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, Jules Pretty and colleagues (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 four 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 percent (geometric mean 64 percent). All crops showed water use efficiency gains, with the highest improvement in rainfed crops. The analysis of pesticide-use practices showed that of projects that provided data, 77 percent had a decline in pesticide application by 71 percent, while crop yields grew by 42 percent. Potential carbon sequestration amounted to an average of 0.35 metric tons of carbon per hectare per year (t-C/ha/yr). But when projected into the future, the researchers found that global carbon sequestration could be 0.1 gigatons C/yr if only a quarter of the total area in each farm studied adopted sustainable practices. The farmers studied increased above-ground carbon sinks on their land by improving the organic matter in their soil. Although it is uncertain whether these approaches can meet future food needs, Pretty and his co-authors argue "there are grounds for cautious optimism, particularly as poor farm households benefit more from their adoption" (2006: 1114).

KNOWLEDGE AND LABOUR CONSTRAINTS

However, there are other recent studies that call into question the kinds of positive findings that Pretty and others have produced. For example, a research team led by Robert Tripp (2006) recently conducted a detailed review of the literature and the results of three carefully designed field studies that examined farmers' practices in Honduras, Kenya and Sri Lanka in areas where major, successful programmes had been carried out employing 'low-external input technology' (LEIT). The studies specifically sought to understand the long-term consequences of such efforts. Many of the case examples of low-external-input technologies require significant labour and skill inputs. But who has the labour and skills for such innovations and flexible responses to uncertainty, and how are these acquired?

Tripp and colleagues examined the 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.

Poor farmers often require hands-on experience before they are motivated to utilise many of these agroecological approaches. In some cases the resource-conserving technologies are quite visible to neighbouring farmers, who are capable of copying the ideas with a minimum of experience. In other cases farmers need a period to learn and experiment with the technology and the experience is more difficult to communicate. Furthermore, in cases where complex principles are the basis for a change in practice (e.g. agroecosystem analysis and the rationale for IPM and INM) farmers may find it particularly challenging to articulate what they have learned to their neighbours. The lack of diffusion of the IPM message for irrigated rice, despite the success of farmer field schools in Asia (cf. Berg and Jiggins 2007) is a challenge to conventional assumptions concerning the diffusion of Agroecological Alternatives (Tripp et al., 2005).

A key conclusion of Tripp's book is that 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. There is a need to use a diversity of methods too – and not just the current fads – and develop robust institutions, both at local level, but critically at national and international levels, which see the challenge of technology innovation and development in a more rounded, comprehensive way (Cernea and Kassam 2005).

Given this background, it is clear that, to support pathways to sustainability, such approaches need to focus on more than developing resource-conserving technologies and integrated techniques. They must encompass the complexity of resource use by addressing both the biophysical and social dimensions of agriculture, including equity of distribution of benefits (Conway 2007, 1985). When the scope of these alternative approaches extend beyond the production field, they can help to understand and assess broader interactions and processes in agri-food systems, including conversion of natural resources, efficiency of production, processing of food items, marketing and consumption issues. This allows an analysis of dynamic interactions throughout the entire system, and provides tools to look at the global food chain in comparison to local food systems. Such an analysis includes the impacts of regulations and policies at all levels, as well as the potentials and applications of new technologies, and their overall environmental impact.

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 (Stringer, et al., 2006; Gunderson 1999). This calls for far greater appreciation of local farming practices and knowledge used by rural people to manage their own food systems. This realisation suggests practical new avenues for technical support in which farmers' own priorities, knowledge, perspectives, institutions, practices and indicators gain validity. Thus, another highly relevant stream of work, which is complementary to, but distinct from the Agroecological Alternatives is centred on farmers' participation in research and development.

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).

The kind of knowledge that emerges from these processes has been well described by James Scott (1998), who speaks of 'forms of knowledge embedded in local experience' – *mêtis* – which he sharply contrasts with 'the more general, abstract knowledge displayed by the state and technical agencies'. *Mêtis,* says Scott, 'is plastic, local and divergent... It is, in fact, the idiosyncrasies of *mêtis,* its contextualities, and its fragmentation that make it so permeable, so open to new ideas'. As he suggests: '*mêtis,* with the premium it places on practical knowledge, experience and stochastic reasoning, is of course not merely the now-superseded precursor of scientific knowledge. It is a mode of reasoning most appropriate to complex material and social tasks where the uncertainties are so daunting that we must trust our (experienced) intuition and feel our way.' In addition to experience and intuition, the power of the 'practised eye', *mêtis* is also about experimentation, precise skills and complex knowledge (Scott 1998: 327). Thus, as Paul Richards (1993; 1989; 1985) 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 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 farmers (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.

Recently, Julian Gonsalves and his colleagues (2005) produced a three-volume compendium on *Farmer Participation in Agricultural Research*, for the International Development Research Centre (IDRC) of Canada. In the first volume, Scott Killough (2005: 1) of World Neighbors, writing on participatory approaches to agricultural research and extension, commented:

> The rise of farmer participatory research (FPR) was a deliberate effort among agricultural professionals to combine farmers' indigenous traditional knowledge (ITK) with the more widely recognized expertise of the agricultural research community. The approach aimed to distinguish itself from farming systems research (FSR) in its more deliberate attempt to actively involve

> farmers in setting the research agenda, implementing trials and analyzing findings and results... FPR has gone beyond the on-farm trials which became the standard of FSR, and actually called for farmers to design, monitor and evaluate experiments – in collaboration with researchers – carried out in their own fields.

Thus, participatory approaches are envisioned to help agricultural R&D to respond to problems, needs and opportunities identified by local agents; identify and evaluate technology options that build on local knowledge and resources; ensure that technical innovations are appropriate for local socio-economic, cultural and political contexts; and promote wider sharing and use of agricultural innovations (Collinson 2000). In contrast to the linear process of technology generation–transfer–utilisation in conventional approaches, such approaches encompass a broader set of phases and activities including:

- assessment and diagnosis: situation analysis, needs and opportunities assessment, problem diagnosis, documentation and characterization.
- experimenting with technology options: joint agenda setting for experimentation, technology development and evaluation, integration of technology components and piloting.
- sustaining local innovation: institutionalizing social and political mechanisms, facilitating multi-perspective negotiation and conflict management, community mobilization and action, local capacity development, strengthening local partnerships.
- dissemination and scaling up: development of learning and extension mechanisms, information support to macro-policy development, promoting networking and horizontal linkages.
- managing participatory research and development: project development, resource mobilisation, data management, monitoring and evaluation, capacity development.

In practice, such approaches have been distinguished by key elements such as: sensitivity to users' perspectives, linkage between scientific and local knowledge, interdisciplinarity, multi-agency collaboration, problem- and impact-driven research and development objectives, and a livelihood systems framework. Moreover, 20 years of field experience has shown that innovations for improving agriculture and natural resource management need to address not only the technical challenges confronting small farmers and local resource managers, but also key socio-cultural and political-economic dimensions such as gender roles and relations, power relations, community organisations and institutional arrangements, collective action, property rights and land tenure, policy processes and governance regimes (cf., Thompson 2006; Toulmin and Gueye 2003; Otsuka and Place 2002).

Since engaging with participatory approaches from the 1980s, scientists at international and national agricultural research centres and a variety of public and private agencies have encountered both successes and failures. The early days of debate for and against the participation of farmers and rural people in research have given way to more grounded discussions about appropriate approaches and specific methods for particular circumstances. Rather than advocating one 'brand' of participatory research over another, researchers are innovating and experimenting to match the methods – both quantitative and qualitative – and the situation. They are also working to bring the insights of everyday practice in the field back into the design of new technologies and future research practices, protocols, structures and strategies. Thus, many researchers are not asking if participatory methods should be used, but rather when and how, and which type of method, in combination with which traditional quantitative and qualitative research tools (Holland and Campbell 2005; Kanbur and Shaffer 2005).

Researchers also recognise that the organisation of agricultural research and extension itself was a major reason why science was failing to improve the livelihoods of poor people. 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). It may be the only feasible route for crop breeding in remote regions, where a high level of crop diversity is required within the same farm, or for minor crops that are neglected by formal breeding programmes (Eyzaguire and Iwanaga 1996).

There is a very extensive literature on PPB and participatory technological development more generally, and much of it now emerges in the form of what Piers Blaikie (2006: 1952) has characterised as a: '...burgeoning of manuals on Participatory Rural Appraisal...' While those approaches may have much to contribute, because of their concern with poverty reduction, empowerment and social justice, particularly in terms of inclusion of, and accountability to, the users of the innovations, they have not always taken account the dynamics of broader political economic contexts in which those farmers operate. Nevertheless, however superficially plausible and promising Participatory Alternatives such as PPB are, they have often been unsuccessful on the ground, although rhetorical support amongst international agencies and many NGOs remains high. In practice, participatory R&D programmes have sometimes failed in the sense that they have often not delivered many or all of the anticipated benefits, and occasionally they have been counter-productive. Those problems have frequently been a consequence of serious misunderstandings on the part of outsiders concerning the predicaments and perspectives of the local people. In particular, they have sometimes not taken local dynamics seriously and, therefore, not adequately addressed intra- and inter-community differences of power and the social tensions that arise over differential access and control of resources and institutions (cf. Guijt and Shah 1998; Scoones and Thompson 1994).

This does not repudiate the goal of facilitating pathways out of poverty by empowering local communities to take more control over their own material circumstances, but it does raise questions about higher-level interfaces involving national politics between administrations, policy elites and external support agencies. In other words, the manner in which local challenges can be addressed by and with the rural poor should take into account not only indigenous knowledge and practices, but also the dynamics and governance issues at higher 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 will be 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 (Blaikie 2006; Bebbington and Thompson 2004).

7. COMPETING VISIONS OF SUSTAINABILITY

These different narratives of agricultural development – focusing on technology, growth, agroecology and participation – suggest very different visions of Sustainability. Recalling the now classic description of sustainable development as three overlapping circles representing 'economics', 'environment' and 'society', each emphasises different dimensions. Thus 'modern' agriculture, with its emphasis on technology and growth, represents a productionist vision of sustainability, with economics the key focal point. Technology-driven economic growth through sustained innovation and trade is the envisaged pathway, providing transitions out of agriculture or a shift of subsistence-oriented 'old' agriculture to a modern, commercial, 'new' form of agriculture, with wider poverty reduction aims achieved through trickle-down and employment benefits from improved agriculture-led growth.

The agroecological approach, by contrast, focuses more on environmental dimensions of sustainability. Emerging out of a critique of the productionist paradigm and in response to the second-generation impacts of the Green Revolution, Agroecological Alternatives emphasise pathways of change which work with natural systems, generating production and improved livelihoods with more ecologically-attuned production systems. Participatory Alternatives, in turn, emphasise societal dimensions, with the empowerment of farmers being seen as central to achieving both economic and ecological sustainability.

Different framings of the debate therefore suggest different pathways to sustainability, based on different assumptions about economic, socio-political, technological and ecological systems and their dynamics. As we have shown, each of these narratives of agricultural change has its clear limits too. A key challenge for the future – and central to the STEPS research agenda – is to identify ways forward which are responsive to current and changing conditions, as well as meeting the wider, normative goals of sustainability.

In our view, to move these goals forward the current debate about the future of agri-food systems needs refreshing. The mainstream perspective, centred on the production-growth nexus, has received substantial attention in recent years, and is once again seen as the sole way forward. Alternatives are often dismissed as unrealistic and only relevant on the micro-project scale. There has been an unhelpful and unproductive slanging match framed in either/or terms between different groups. The debate about genetically-modified crops, and biotechnological approaches in agriculture, has perhaps been the most heated in recent years, with the middle ground disappearing in a welter of accusations and ripostes. But, as we have explored, much of this debate misses the point, as the important issues are more fundamental than whether a particular technology or policy is 'good' or 'bad' and lead us into a more complex 'science of the gray' (Stone 2002, 2005). The question that does need to be asked is about the framing of approaches and broader trajectories of socio-technical change. These upstream choices about policy frameworks or innovation options are at core political, requiring rather basic shifts in the governance of agri-food systems than is recognised by any of the current narratives of agricultural development.

That said, whether one looks at Asian or Latin American agriculture or the more recent rush to revitalise agriculture in Africa, the prevailing vision is that a 'modern' agriculture (from the Green Revolution to the recent Gene Revolution) remains the standard, preferred pathway to development. Such a perspective – centred on technology, production and growth – constructs 'the system' in particular ways. Thus the key elements of the modern agri-food 'system' (what's in it, how it's bounded) focus on a wide array of external inputs (R&D, fertilisers, seeds, irrigation, markets) and emphasising functions (what it's for, who it serves) in terms of 'outputs' (yield – breaking the productivity gap) leading to 'pro-poor' gains through a diversity of direct and indirect routes.

As already mentioned, the predominant view in policy and scientific circles is that the first Green Revolution was a success – particularly for certain Asian farmers growing certain crops in certain places over a certain time period. It prevented a Malthusian disaster in global food markets in the wake of the rapid population expansion realised in virtually all developing countries after World War II. This Malthusian outcome in the form of high food prices and land scarcity (with attendant high land rents and prices) did not occur in the increasingly globalised economy. Consequently, world prices of most agricultural crops in real terms declined after 1950, which drove economic growth and facilitated mass rural-urban migration. Many developing countries, particularly in Africa, however, have not realised a Green Revolution and, consequently, do not produce enough food to feed their growing populations, even with equitable distribution. Microeconomic conditions in poor areas render agricultural production and trade risky and costly, militating directly against adoption and diffusion of improved technologies (cf. Omamo and Naseem 2005; Fafchamps 1992; Binswanger and McIntire 1987). Thus, the justifications for policy interventions that mirror the Asian success story are strong.

For many involved in mainstream agricultural development, a key part of the answer is a biotech or Gene Revolution. This perspective argues that it is the natural successor to the Green Revolution, although thus far significant benefits to poor farmers in developing countries are rather limited. The emphasis of this new revolution is once again to move beyond complexity and diversity, rather than to respond and adapt to them. GM crops introduced so far have typically followed this pattern of single new traits, but they have not been designed to be 'pro-poor' nor are they by-and-large 'pro-poor' in practice (Eicher, et al. 2006; Scoones 2005). This pathway – and associated socio-political-technical framings – has been institutionalised within the CGIAR and the national agricultural research systems (Spielman 2006).

To complicate matters further, this new revolution is being led by major private sector 'life sciences' companies, who invest large sums of money in R&D in biotechnology and is based on a particular set of governance arrangements – professions, organisation, incentives, intellectual property rights, shrinking state provision and so on. The result is that agricultural science and technology (derived from agronomy and plant breeding, and now increasingly biotechnology) is being combined with growth-oriented development (derived from versions of neo-liberal agricultural economics) targeted at global markets. This narrative, as discussed earlier, focuses on issues of quality, health and hygiene standards, market integration, product standardisation and intellectual property rights. It assumes that economic growth in many developing countries will be achieved mainly through technology-led growth in commercial agriculture. This is heralded as the way to meet the MDGs and other key development and poverty reduction targets. In many developing countries current government agricultural policy, backed by international development agencies, is to support large commercial farms on the one side with a different range of policies (including social protection) for the 'small farm sector' on the other, thus promoting an essentially dualistic system for agriculture in the name of poverty reduction.

Such a vision, when promulgated by the world's most powerful public and private research and development institutions, can lead to a dominant 'lock-in' of certain policies and associated narratives of agricultural change that 'lock-out' alternative pathways and perspectives (Berkhout 2002; Ruttan 1997). It also reveals how technological developments in agriculture tend to be incremental and path dependent owing to:

- the cognitive frameworks, routines, resources, capabilities and knowledge of technology producers – both publicly funded research centres and private companies – and technology users, and expectations about what kinds of innovations will be beneficial in future;
- the way specific socio-technical practices are embedded within wider, facilitating infrastructures (such as the CGIAR and associated NARS

linked to the international network of donor agencies), which subsequently restrict opportunities for alternatives;

- incumbent practices enjoy economies of scale (e.g. mass markets) and positive network externalities that have been built up over long periods of investment (i.e. it is easier and less risky to follow established practices than to invest in alternatives, particularly if these involve handing greater control to poor people);
- the co-evolution of institutions with technological practices and processes, like government policies, market regulations and professional associations (e.g. agricultural economists; agronomists; engineers; etc.) that reinforce existing trajectories;
- prevailing market and social norms influence the kinds of performance deemed satisfactory, and the lifestyle routines and norms that develop within the agricultural professions (both among natural and social scientists), which embed these practices further;
- agricultural education at both secondary and tertiary levels further reinforces this path-dependence through use of obsolete textbooks, uninspired curricula and conservative career structures, thus helping to reproduce the dominant discourses and mindsets (Chambers 1993).

CONTEMPORARY CHALLENGES

Given the dominance of this framing, its path-dependent nature and the growing complexity and uncertainty confronting today's food systems at all scales, one must ask how appropriate is this prevailing vision of modern agriculture? While the Agroecological and Participatory Alternatives discussed earlier offer partial responses, they too are limited in the face of growing challenges. Any discussion of the sustainability of agri-food systems, we suggest, must address four such challenges characterised by different aspects of system dynamics and governance.

1. **Dynamic human-environment interactions**. 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 which affect the system properties of durability, robustness, resilience and stability (cf. STEPS Working Paper 1 on Dynamics). Climate change and the

impacts of increased variability of rainfall present particular challenges, especially in drier, rainfed cropping systems (IPCC 2007). 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) (Sutherst 2004) or the prevalence of major epidemics (such as HIV/AIDS) have major 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.

2. **Beyond the Green Revolution: technology challenges**. 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 1993, 1989). 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 (Leach and Scoones 2006; Leach, et al. 2005). 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.

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, even those related to Participatory Alternatives, 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 (cf. Ingco and Nash 2004; Wade 2003). 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 and to whose benefit.

4. **Global citizens and consumers**. 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 (Tansey and Worsley 1995). Citizen-led campaigns which seek to reclaim control over their food systems argue for 'food sovereignty' (cf. Windfuhr and Jonsén 2005), local production/consumption and 'good' food (organics, food miles, fair trade), raising cross-sectoral concerns about health (e.g. in relation to debates about obesity, GM foods etc.) and the environment (pollution, agrobiodiversity, etc.) (Millstone and Lang 2002). Food and food production has become an important political agenda in the North, and particularly in Europe (Friedberg 2004; Lang and Heasman 2004). The associated shifts in patterns of demand have opened up opportunities for niche marketing (e.g. in organic products) but also closed down other options (e.g. through food miles restrictions) for developing country producers (MacGregor and Vorley 2006). At the same time, as such debates are shaping consumer preferences in some parts of the world, new demand notably in Asia is opening up, as urbanisation and economic growth continues apace. How this affects overall demand and consumer preferences remains uncertain, but it will continue to be an important driver in the future of agri-food systems globally.

Taken together, these challenges highlight some important new dimensions for 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. As discussed above, critical features of this approach include analysing the patterns of interaction that produce outcomes. This means recognising the continual occurrence of feedbacks as critical for adaptation and dynamics and acknowledging that uncertainty and surprises are the norm. In other words, we are always managing in a context of change.

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'. It assumes that not every outcome is governed solely by macro-level or structural features, but by interactions between local agency and wider structural forces (Clark 1998). Thus, individuals and their social networks can and do also make a difference. These actors – including poor producers and consumers – affect change through their agency, drawing on their knowledge and understanding, and develop and maintain certain institutions by their actions. Although institutions and structures govern people's actions, the structures are also modified over time as a result of individual and collective actions (Leach, et al. 1999). This evolution in thinking about social systems, commonly known as 'structuration' (Giddens 1986), has also been characterised by a recognition of the importance of heterogeneity among households, communities and institutions themselves. 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. The final section, therefore, lays out some of the elements of such an approach.

8. CONCLUSIONS: PATHWAYS TO SUSTAINABLE AGRI-FOOD SYSTEMS

Outside pockets of well-resourced agricultural areas, where road, irrigation and other infrastructure is well developed, the achievements of the 'market modernism' vision of agriculture, as discussed, has been patchy. New attempts to extend Green Revolution successes to Africa through a number of high-profile, well-resourced initiatives, such as the Millennium Villages project or the Alliance for a Green Revolution in Africa (AGRA) initiative, though the sustainability of both efforts have been questioned (cf. Cabral, et al. 2006; Holt-Gimenez, et al. 2006; GRAIN 2006). As the scourge of poverty and ill-being becomes a global political debate (UN Human Development/MDGs, 'Make Poverty History' campaign, etc.), how can livelihood improvement and poverty reduction be put centre-stage? As discussed in earlier sections, there are potentially multiple routes to such goals through both direct and indirect trickle-down benefits. But systematic analysis of the contextual factors that influence poverty impacts are few and far between, and usually shrouded in a thick fog of 'pro-poor' rhetoric. In our focus on pathways to Sustainability – with a capital 'S' – a systematic assessment of these diverse trajectories is critical, together with a commitment to exploring the pros, cons and trade-offs of different future scenarios.

In rethinking agri-food systems in both the industrialised and the developing world, therefore, we must ask some challenging questions. For example, given growing uncertainty and complex dynamics – in ecological, economic and socio-political settings – how resilient and robust are different alternative approaches to agricultural development in the face of contemporary shocks and stresses in both the North and the South? How does the governance of global and local agri-food systems need to be thought about in the light of the major restructuring of R&D and innovation systems and the growing global politics of food? What does this mean for different normative understandings of Sustainability, as expressed by different groups? And, perhaps most importantly, what does this imply for different pathways of change in different contexts?

To conclude, we offer six elements of a STEPS research agenda on agri-food systems:

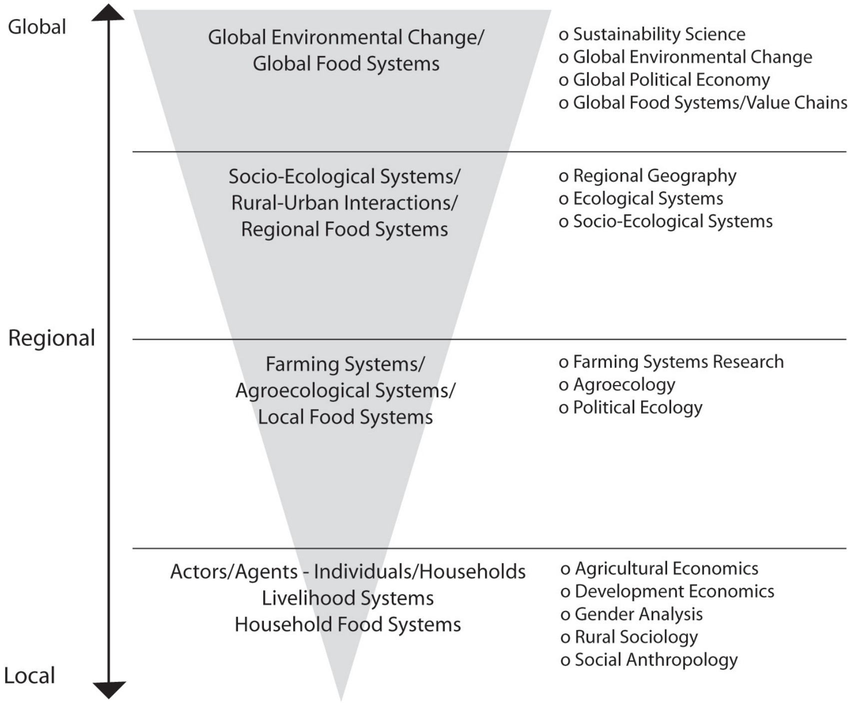
1. **Framing the sustainability challenge**. A key first step is to unpack what is meant by sustainability in agri-food systems. This requires an analysis of and reflections on different framings involving deliberations among the key actors involved (farmers, consumers, processors, R&D players and others). 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. 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. 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.

2. **Exploring multiple pathways**. Given the diversity of 'rural worlds', and the importance of history and context on 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.

3. **Scales of analysis**. 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. Figure 2 offers an overview of the type of cross-disciplinary interactions required.

Figure 2. Cross-Scale Interactions and Disciplinary Contributions



4. **Dynamic system properties**. In thinking about pathways to sustainability and their scale interactions, a key set of questions centres on the dynamic properties of such options. How do the variety of different pathways (normatively, politically defined) respond to internal and external shocks and stresses, and how resilient, robust, durable and stable are they? Depending on who is pursuing a particular pathway, different system attributes may be more or less desirable. Debates about trade-offs between these are therefore key, as are discussions about how these are affected at different scales: for example, a resilient system at one scale may look less so at another, and taken together a diversity of options may look more or less appropriate. This requires an engagement with issues of uncertainty and complexity in a framework for analysis and action that takes such issues as central (cf. STEPS Working Paper 1 on Dynamics).

5. **Governance analysis**. With pathways to sustainability defined in relation to normative-political choices of diverse actors, a critical set of issues hinges on questions of governance (cf. STEPS Working Paper 2 on Governance). 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's 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. **From analysis to practice**. Cross-cutting all these elements there is a more forward-looking, pragmatic challenge: how to facilitate the design of agri-food systems that meet the challenge of sustainability in the future? This requires thinking hard about approaches to appraisal (cf. STEPS Working Paper 3 on Designs), but also about the wider processes which affect what happens on the ground – whether in terms of the political and policy processes that shape debates and get different framings on the table or the more technical, administrative and managerial challenges of designing innovation systems which are more responsive to new demands.

In sum, in this paper we have argued that 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 agro-ecology and participatory research and development are not fully able respond to the dynamic character of complex and rapidly changing agri-food systems.

This paper makes the case for a deeper understanding of diverse 'rural worlds' and their potential pathways to Sustainability through agriculture. Moreover, it calls 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 emerging interdisciplinary research agenda on agri-food systems for STEPS that focuses on dynamic system interactions in risk-prone environments and explores how pathways can become more resilient and robust in an era of growing complexity and uncertainty.

REFERENCES

Abler, D.G. and Sukhatme, V.A. (2006) 'The "Efficient but Poor" Hypothesis', *Review of Agricultural Economics* 28.3: 338–343.

Adger, W.N. (2006) 'Vulnerability'. *Global Environmental Change*, 16(3): 268-281.

Adger, W.N., Arnell, N. W. and Tompkins, E.L., eds. (2005) Adaptation to Climate Change: Perspectives across Scales. Special issue of *Global Environmental Change* 15(2).

Allen, R.C. (1991) 'The Two English Agricultural Revolutions, 1459-1850', in Campbell, B.M.S. and Overton, M., eds, *Land, Labour and Livestock: Historical Studies in European Agricultural Productivity*, Manchester: Manchester University Press.

Almond, F.R. and Hainsworth, S.D., eds (2005) 'Beyond Agriculture – Making Markets Work For The Poor, Proceedings of an International Seminar, 28 February–1 March 2005, Westminster, London, UK; DFID Crop Post-Harvest Workshop, http://www.cphp.uk.com/network/default.asp?step=4&pid=47 (11 May 2007).

Alston, J.M., Chan-Kang, C., Marra, M.C., Pardey, P.G. and Wyatt, T.J. (2000) 'A Meta–Analysis of Rates of Return to Agricultural R&D: Ex Pede Herculem?', *IFPRI Research Report* 113, Washington, D.C.: International Food Policy Research Institute.

Altieri, M. (1995) *Agroecology: The Science of Sustainable Agriculture*, second edition, Boulder, CO: Westview Publications.

Altieri, M. (2002) 'Agroecological Principles of Sustainable Agriculture', in Uphoff, N., ed., *Agroecological Innovations: Increasing Agricultural Production with Participatory Development*, London: Earthscan.

Altieri, M. (2004) 'Agroecology versus Ecoagriculture: Balancing Food Production and Biodiversity Conservation in the Midst Of Social Inequity', Geneva: International Union for Conservation of Nature and Natural Resources (IUCN) / World Conservation Union, http://www.iucn.org/themes/ceesp/Publications/occasional%20papers/Occasional%20Paper%20-%20Altieri.pdf (11 May 2007).

Anderson, K., Martin, W. and Valenzuela, E. (2006) 'The Relative Importance of Global Agricultural Subsidies and Market Access', *World Trade Review* 5.3, November, Washington, D.C.: The World Bank, http://siteresources.worldbank.org/INTRANETTRADE/Resources/Relatve_ImportanceOf_Global_Agric_Subsidies&Market_Access_revised_March06.pdf (11 May 2007).

Barrett, C.B. and Swallow, B.M. (2004) 'Dynamic Poverty Traps and Rural Livelihoods', in Ellis, F. and Freeman, A., eds, *Rural Livelihoods and Poverty Reduction Policies,* London: Routledge.

Bebbington, A. and Thompson, J. (2004) 'Use of Civil Society Organizations to Raise the Voice of the Poor in Agricultural Policy', *DFID RNRA Team Working Paper* 14, London: Department for International Development, http://dfid-agriculture-consultation.nri.org/summaries/wp14.pdf (11 May 2007).

Berg, H. van den, and Jiggins, J. (2007) 'Investing in Farmers: The Impacts of Farmer Field Schools in Relation to Integrated Pest Management', *World Development* 35 (4): 663-686.

Berkes, F., Colding, J. and Folke, C., eds (2003) *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change,* Cambridge: Cambridge University Press.

Berkhout, F. (2002) 'Technological Regimes, Path Dependency and the Environment', *Global Environmental Change* 12.1: 1-4.

Bezemer, D. and Headey, D. (2006) 'Something of a Paradox: The Curious Neglect of Agriculture in Development', *Working Paper Series* 01/2006, St. Lucia, Queensland: Centre for Efficiency and Productivity Analysis, School of Economics, University of Queensland. http://www.uq.edu.au/economics/cepa/docs/WP/WP012006.pdf (11 May 2007)

Binswanger, H. and McIntire, J. (1987) 'Behavioural and Material Determinants of Production Relations in Land-abundant Tropical Agriculture', *Economic Development and Cultural Change* 36: M73-99.

Blaikie, P. (2006) 'Is Small Really Beautiful? Community-based Natural Resource Management in Malawi and Botswana', *World Development,* 34.11: 1942-1957.

Bonnano, A., Busch, L., Friedland, W., Gouveia, L., and Mingione, E., eds, (1995) *From Columbus to ConAgra: The Globalization of Agriculture and Food,* Lawrence: University of Kansas Press.

Boserup, E. (1965) *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure,* Chicago: Aldine.

Brokensha, D., Warren, D. and Werner, O., eds (1980) *Indigenous Knowledge Systems and Development,* Lanham: University Press of America.

Brooks, S. (2005) 'Biotechnology and the Politics of Truth: From the Green Revolution to the Evergreen Revolution', *Sociologia Ruralis* 45.4: 360-379.

Brown, L. and Kane, H. (1994) *Full House: Reassessing the Earth's Population Carrying Capacity,* New York: Norton.

Byerlee, D. and Alex, G.E. (1998) 'Strengthening National Agricultural Research Systems: Policy Issues and Good Practice', *Environmentally and Socially Sustainable Development Series,* Washington, D.C.: The World Bank.

Cabral, L. and Scoones, I. (2006) 'Narratives of Agricultural Policy in Africa: What Role for Ministries of Agriculture?', draft paper presented at the Future Agricultures Consortium Workshop, Institute of Development Studies, UK, 20-22 March 2006, http://www.future-agricultures.org/pdf%20files/MoA_paper.pdf (11 May 2007)..

Cabral, L., Farrington, J. and Ludi, E. (2006) 'The Millennium Villages Projects – A New Approach to Ending Rural Poverty in Africa?', *ODI Natural Resources Perspectives* 101, August, London: Overseas Development Institute, http://www.odi.org.uk/nrp/nrp101_web.pdf#search=%22odi%20millenium%20villages%22 (11 May 2007)..

Carrol, C.R., Vandermeer, J.H. and Rosset, P.M. (1990) *Agroecology,* McGraw Hill Publishing Company: New York.

Cernea, M.M. and Kassam, A.H., eds (2006) *Researching the Culture in Agri-Culture: Social Research for International Agricultural Development,* CGIAR Science Council, Wallingford, UK: CABI Publishing.

Chambers, R. (1991) 'Complexity, Diversity and Competence: Toward Sustainable Livelihood from Farming Systems in the 21st Century', *Journal of the Asian Farming Systems Association* 1.1: 79-89.

Chambers, R. (1993) *Challenging the Professions: Frontiers for Rural Development,* London: Intermediate Technology Publications.

Chambers, R., Longhurst, R. and Pacey, A., eds (1981) *Seasonal Dimensions to Rural Poverty.* London: Frances Pinter.

Chambers, R., Thrupp, L-A. and Pacey, A., eds (1989) *Farmer First: Farmer Innovation and Agricultural Research,* London: Intermediate Technology Publications.

Chataway, J. (2005) 'Introduction: Is It Possible to Create Pro-Poor Agriculture-Related Biotechnology?', *Journal of International Development* 17.5: 597-610.

Clark, W.M. (1998) 'Agents and Structures: Two Views of Preferences, Two Views of Institutions', *International Studies Quarterly,* 42: 245-270.

Collinson, M., ed. (2000) *A History of Farming Systems Research.* Oxford: Oxford University Press.

Conway, G. (1985) 'Agroecosystems Analysis', *Agricultural Administration,* 20: 31-55.

Conway, G. (1997) *Doubly Green Revolution: Food for All in the Twenty-First Century,* London: Penguin Books.

Conway, G. (2007) 'A Doubly Green Revolution: Ecology and Food Production', in May, R.M. and McLean, A.R., eds, *Theoretical Ecology: Principles and Applications,* Oxford: Oxford University Press.

Conway, G. and Barbier, E. (1990) *After the Green Revolution: Sustainable Agriculture for Development,* London: Earthscan Publications.

Conway, G. and Toenniessen, G. (1999) 'Feeding the World in the Twenty-First Century. *Nature* 402 (6761) Suppl: C55-58.

Conway, G. and Toenniessen, G. (2003) 'Science for African Food Security', *Science* 299, 21 February: 1187-1188.

Cullather, N. (2004) 'Miracles of Modernisation: The Green Revolution and the Apotheosis of Technology', *Diplomatic History,* 28.2: 227-254.

Davis, B., Reardon, T., Stamoulis, K.G. and Winters, P. eds. (2002) *Promoting Farm/Non-farm Linkages for Rural Development: Case Studies from Africa and Latin America,* Rome: Food and Agriculture Organization of the United Nations. ftp://ftp.fao.org/docrep/fao/005/y4383E/y4383E00.pdf

de Gorter, H. and Hranaiova, J. (2004) 'Quota Administration Methods: Economics and Effects with Trade Liberalization', in Ingco, M. and Nash, D., eds, *Agriculture and the WTO: Creating a Trading System for Development,* Washington, DC: World Bank.

DFID (2005) 'Growth and Poverty Reduction: The Role of Agriculture', *DFID Policy Paper,* London, UK: Department for International Development, http://www.dfid.gov.uk/pubs/files/growth-poverty-agriculture.pdf (11 May 2007)..

Diao, X., Fekadu, B., Haggblade, S., Taffesse, A.S., Wamisho, K. and Yu, B. (2007) 'Agricultural Growth Linkages in Ethiopia: Estimates using Fixed and Flexible Price Models', *IFPRI Discussion Paper* 00695, March, Washington, D.C.: International Food Policy Research Institute, http://www.ifpri.org/pubs/dp/IFPRIDP00695.pdf (11 May 2007).

Dorward, A., Kydd, J. and Poulton, C. (2005) 'Beyond Liberalisation: "Developmental Coordination" Policies for African Smallholder Agriculture', Special Issue on New Directions for African Agriculture, *IDS Bulletin* 36.2: 80-85, http://www.future-agricultures.org/pdf%20files/Dorward.pdf (11 May 2007).

Dorward, A., Kydd, J., Morrison, J. and Urey, I. (2004) 'A Policy Agenda for Pro-Poor Agricultural Growth', *World Development,* 32.1: 73-89.

Dowie, M. (2001) *American Foundations: An Investigative History,* Cambridge, MA: The MIT Press.

Drèze, J. and Sen, A.K. (1989) *Hunger and Public Action,* Oxford: Clarendon Press.

Dyson, T. (1996) *Population and Food: Global Trends and Prospects,* New York: Routledge, New York.

Edstrom, J. and Samuels, F., with Haddad, L., Proudlock, K., Young, I. and Bongartz, P. (2007) 'Linking HIV and AIDS to Nutrition, Food Security and Livelihoods in Sub-Saharan Africa: Principles for Policy Guidance from Reflection on Current Evidence and Debates', Draft report for the UK Department of International Development, Brighton: Institute of Development Studies.

Ehrlich, P. R. and Ehrlich, A. H. (1990) *The Population Explosion,* New York: Simon & Schuster.

Eicher, C. K. and Staatz, J. M., eds (1998) *Agricultural Development in the Third World,* third edition, Baltimore, MD: Johns Hopkins University Press.

Eicher, C.A., Maredia, K. and Sithole-Niang, I. (2006) 'Crop Biotechnology and the African Farmer', *Food Policy* 31: 504–527.

Ericksen, P. J. (2006a) 'Assessing the Vulnerability of Food Systems to Global Environmental Change: A Conceptual and Methodological Review', *GECAFS Working Paper,* 3, Wallingford, UK: GECAFS International Project Office, NERC-Centre for Ecology & Hydrology.

Ericksen, P. J. (2006b) 'Conceptualizing Food Systems for Global Environmental Change (GEC) Research', *GECAFS Working Paper,* 2, Wallingford, UK: GECAFS International Project Office, NERC-Centre for Ecology & Hydrology.

Evans, L. T. (1998) *Feeding the Ten Billion: Plants and Population Growth,* Cambridge: Cambridge University Press.

Evenson, R. E. and Gollin, D. (2000) 'Assessing the Impact of the Green Revolution: 1950-2000', *Science,* 300, 2 May: 758-762.

Eyzaguire, P. and Iwanaga, M., eds (1996) *Participatory Plant Breeding,* Rome: International Plant Genetics Research Institute.

Fafchamps, M. (1992) 'Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World', *American Journal of Agricultural Economics,* 74: 90-99.

Fan S., Hazell, P. and Haque, T. (2000) *Role of Infrastructure in Production Growth and Poverty Alleviation in Rural India,* Washington, D.C.: The World Bank.

Fan, S., Zhang, L. and Zhang, X. (2001) 'Growth and Poverty in Rural China: The Role of Public Investment', *EPTD Discussion Paper,* 66, Washington, D.C.: International Food Policy Research Institute.

FAO, IFAD and WFP (2002) 'Reducing Poverty and Hunger: The Critical Role of Financing for Food, Agriculture and Rural Development', paper prepared for the International Conference on Financing for Development, Monterrey, Mexico, 18-22 March 2002, Rome: Food and Agriculture Organisation of the United Nations, International Fund for Agricultural Development and the World Food Programme, ftp://ftp.fao.org/docrep/fao/003/Y6265E/Y6265E.pdf (11 May 2007).

Fischer, G., Shah, M. and van Velthuizen, H. (2002) *Climate Change and Agricultural Vulnerability,* Laxenburg: International Institute for Applied Systems Analysis.

Flores, M. (2004) 'Conflict, Rural Development and Food Security in West Africa', *ESA Working Paper,* 04-02, January, Rome: Food and Agriculture Organisation of the United Nations, ftp://ftp.fao.org/docrep/fao/007/ae057e/ae057e00.pdf (11 May 2007)

Folke, C. (2006) 'Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses', *Global Environmental Change* 16(3): 253-267.

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., Salomonsson, L., Helenius, J., Rickerl, D., Salvador, R., Wiedenhoeft, M., Simmons, S., Allen, P., Altieri, M., Flora, C. and Poincelot, R. (2003) 'Agroecology: The Ecology of Food Systems', *Journal of Sustainable Agriculture,* 22.3: 99-118.

Friedberg, S. (2004) 'The Ethical Complex of Corporate Food Power', *Environment and Planning D: Society and Space,* 22: 513 -531, http://www.dartmouth.edu/~geog/facstaff/CVs/Freidberg/EthicalComplex.pdf (11 May 2007)).

Funtowicz, S.O., and Ravetz, J.R. (1990) *Uncertainty and Quality in Science for Policy,* Kluwer: Dordrecht, Netherlands.

Gaud, W.S. (1968) 'The Green Revolution: Accomplishments and Apprehensions', address by the Honourable William S. Gaud, Administrator, U.S. Agency for International Development, Department of State, before the Society for International Development, Shorehan Hotel, Washington, D.C., 8 March 1968, http://www.agbioworld.org/biotech-info/topics/borlaug/borlaug-green.html (11 May 2007).

Giddens, A. (1986) *The Constitution of Society: Outline of Theory of Structuration,* Berkeley: University of California Press.

Gillespie, S., ed. (2006) 'AIDS, Poverty, and Hunger: Challenges and Responses', Highlights of the International Conference on HIV/AIDS and Food and Nutrition Security, Durban, South Africa, April 14-16, 2005, Washington, D.C.: International Food Policy Research Institute, http://www.ifpri.org/pubs/books/oc50/oc50.pdf (11 May 2007)).

Gliessman, S. (2006) *Agroecology: The Ecology of Sustainable Food Systems,* second edition, Boca Raton, FL: CRC Press.

Gonsalves, J., Becker, T., Braun, A., Campilan, D., de Chavez, H., Fajber, H., Kapiriri, M., Rivaca-Caminade, J. and Vernooy, R., eds (2005) *Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A Sourcebook;* Three Volumes: Volume 1: *Understanding Participatory Research and Development,* http://www.idrc.ca/en/ev-73443-201-1-DO_TOPIC.html (11 May 2007); Volume 2: *Enabling Participatory Research and Development,* http://www.idrc.ca/en/ev-73444-201-1-DO_TOPIC.html (11 May 2007); Volume 3: *Doing Participatory Research and Development,* http://www.idrc.ca/en/ev-73446-201-1-DO_TOPIC.html (11 May 2007), Laguna, Philippines and Ottawa, Canada: International Potato Center and International Development Research Centre.

GRAIN (2006) 'Another Silver Bullet for Africa? Bill Gates to Resurrect the Rockefeller Foundation's Decaying Green Revolution', *Against the Grain,* 7, September, Barcelona: GRAIN.

Griffin, K. (1974) *The Political Economy of Agrarian Change,* London: Macmillan.

Guijt, I. and Shah, M. K., eds (1998) *The Myth of Community: Gender Issues in Participatory Development,* London: Intermediate Technology Publications.

Gunderson, L. (1999) 'Resilience, Flexibility and Adaptive Management: Antidotes for Spurious Certitude?', *Conservation Ecology,* 3.1: 7, http://www.consecol.org/vol3/iss1/art7/ (11 May 2007)..

Gunderson, L. H. and Holling, C. S., eds (2002) *Panarchy: Understanding Transformations in Human and Natural Systems,* Washington, D.C.: Island Press.

Gunderson, L. H., Holling, C. S. and Light, S. (1995) *Barriers and Bridges to Renewal of Ecosystems and Institutions,* New York: Columbia University Press.

Haggblade, S., Hammer, J. and Hazell, P. (1991) 'Modeling Agricultural Growth Multipliers', *American Journal of Agricultural Economics,* 73.2: 361-374, http://chla.library.cornell.edu/cgi/t/text/pageviewer-idx?c=chla;cc=chla;sid=0c5f376cd1b0f1df28f74af177da586c;rgn=full%20text;idno=5032826_73_002;view=image;seq=0134 (11 May 2007).

Hazell, P. and Haddad, L. (2001) 'Agricultural Research and Poverty Reduction', *Food, Agriculture and Environment Discussion Paper,* 34, Washington, D.C.: International Food Policy Research Institute and the Technical Advisory Group (TAC), Consultative Group on International Agricultural Research, http://www.ifpri.org/2020/dp/2020dp34.pdf (11 May 2007).

Hazell, P. B. R. and Ramasamy, C., eds (1991) *The Green Revolution Reconsidered: The Impact of High-Yielding Rice Varieties in South India,* Baltimore, MD: John Hopkins University Press for IFPRI.

Heffernan, W. D. with Hendrickson, M. and Gronski, R. (1999) 'Consolidation in the Food and Agriculture System. Report to the National Farmers Union', February 5, Columbia, MI: Department of Rural Sociology, University of Missouri.

Holland, J. and Campbell, J. R. eds (2005) *Methods in Development Research: Combining Qualitative and Quantitative Approaches,* London: Intermediate Technology Publications.

Holling, C.S., ed (1978) *Adaptive Environmental Assessment and Management,* London: John Wiley & Sons.

Holt-Gimenez, E., Altieri, M.A. and Rosset, P. (2006) 'Ten Reasons Why the Rockefeller and the Bill and Melinda Gates Foundations' Alliance for Another Green Revolution Will Not Solve the Problems of Poverty and Hunger in Sub-Saharan Africa', *FoodFirst Policy Brief,* 12, October, San Francisco: FoodFirst/Institute for Food and Development Policy, http://www.foodfirst.org/files/pdf/policybriefs/pb12.pdf (11 May 2007).

Howes, M. and Chambers, R. (1979) 'Indigenous Technical Knowledge: Analysis, Implications and Issues', *IDS* Bulletin, 10.2: 5-11.

IFPRI, ODI and Imperial (2005) 'The Future of Small Farms: Proceedings of a Research Workshop', Wye, UK, June 26-29, 2005, jointly organized by International Food Policy Research Institute (IFPRI) / 2020 Vision Initiative Overseas Development Institute (ODI) and Imperial College, London at Wye, http://www.ifpri.org/events/seminars/2005/smallfarms/sfproc/sfproc.pdf (11 May 2007).

Ingco, M. D. and Nash, J. D., eds (2004) *Agriculture and the WTO: Creating a Trading System for Development,* Washington, D.C.: The World Bank.

IPCC (2007) 'Climate Change 2007: The Physical Science Basis', Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., Geneva: IPCC Secretariat.

Jasanoff, S. (2005) *Designs on Nature: Science and Governance in Europe and the United States,* Princeton: Princeton University Press.

Johnston, B. F. and Mellor, J. W. (1961) 'The Role of Agriculture in Economic Development', *The American Economic Review,* 51.4: 566-593.

Jones, E. L. (1974) *Agriculture and the Industrial Revolution,* Oxford: Basil Blackwell.

Kanbur, R. and Shaffer, P. (2005) 'Epistemology, Normative Theory and Poverty Analysis: Implications for Q-Squared in Practice', *Q-Squared Working Paper,* 2, Toronto: Centre For International Studies, University of Toronto, http://www.q-squared.ca/pdf/Q2_WP2_Kanbur_Shaffer.pdf (11 May 2007)..

Kerkhoff, L. van and Lebel, L. 2006. 'Linking Knowledge and Action for Sustainable Development', *Annual Review of Environment and Resources* 31: 445-477.

Kerridge, E. (1967) *The Agricultural Revolution,* London: Allen and Unwin.

Kerridge, E. (1992) *The Common Fields of England,* Manchester: Manchester University Press.

Killough, S. (2005) 'Participatory Approaches to Agricultural Research and Extension', in Gonsalves, J. et al., eds, *Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A Sourcebook. Volume 1: Understanding Participatory Research and Development,* Laguna, Philippines and Ottawa, Canada: International Potato Center and International Development Research Centre, http://www.idrc.ca/en/ev-73443-201-1-DO_TOPIC.html (11 May 2007).

Klein, P. G. and Cook, M. L. (2006) 'T.W. Schultz and the Human-Capital Approach to Entrepreneurship', *Review of Agricultural Economics,* 28.3: 344-350.

Krueger, A., Schiff, M. and Valdés, A. (1991) *The Political Economy of Agricultural Pricing Policy,* Baltimore, MD: Johns Hopkins University Press.

Kydd, J. and Dorward, A. (2001) 'The Washington Consensus on Poor Country Agriculture: Analysis, Prescription and Institutional Gaps', *Development Policy Review,* 19.4: 467-478.

Lang, T. and Heasman, M. (2004) *Food Wars: The Battle for Mouths, Minds and Markets,* London: Earthscan.

Leach, M. and Scoones, I. (2006) *The Slow Race: Making Technology Work for the Poor,* London: Demos.

Leach, M., Mearns, R. and Scoones, I. (1999) Environmental Entitlements: Dynamics and Institutions in Community-based Natural Resource Management', *World Development,* 27: 225-247.

Leach, M., Scoones, I. and Wynne, B. (2005) *Science and Citizens: Globalization and the Challenge of Engagement,* London: Zed Books.

Lee, K. (1993) *Compass and Gyroscope: Integrating Science and Politics for the Environment,* Washington, D.C.: Island Press.

Leigh, G.J. 2004. *A History of Nitrogen and Agriculture.* Oxford: Oxford University Press.

Lewis, W. A. (1954) 'Economic Development with Unlimited Supplies of Labor', *The Manchester School of Economics and Social Studies,* 22: 139-191.

Lipton, M. (1977) *Why Poor People Stay Poor: Urban Bias in World Development,* London: Temple Smith.

Lipton, M. (2005) 'The Family Farm in a Globalizing World: The Role of Crop Science in Alleviating Poverty', *IFPRI 2020 Policy Brief,* 74, Washington, D.C. International Food Policy Research Institute.

Lipton, M., with Longhurst, R. (1989) *New Seeds and Poor People,* London: Macmillan.

MacGregor, J. and Vorley, B. (2006) '"Fair miles"? The Concept of "Food Miles" through a Sustainable Development Lens', *Sustainable Development Opinion Paper,* London: International Institute for Environment and Development, http://www.iied.org/pubs/pdf/full/11064IIED.pdf (11 May 2007).

Malthus, T. R. (2003) *An Essay on the Principle of Population, as it Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers',* (originally published in 1798), New York: Norton.

McMichael, P., ed. (1994) The Global Restructuring of Agro-Food Systems, Cornell University Press: Ithaca, NY.

Meadows, D. H., Meadows, D. L. and Randers, R. (1992) *Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future,* White River Junction, VT: Chelsea Green.

Mellor, J. W., ed. (1995) 'Agriculture on the Road to Industrialization', Published for the International Food Policy Research Institute, Baltimore and London: The Johns Hopkins University Press, http://www.ifpri.org/pubs/books/Mellor95/Mellor95.pdf (11 May 2007).

Millstone, E. and Lang, T. (2002) *The Atlas of Food: Who Eats What, Where and Why*, London: Earthscan.

Mittal, A. (2006) 'Food Security: Empty Promises of Technological Solutions', *Development*, 49.4: 33–38.

Montgomery, D. R. (2007) *Dirt: The Erosion of Civilizations*, Berkeley: University of California Press.

Mosher, A. T. (1966) *Getting Agriculture Moving: Essentials for Development and Modernization*, New York: Praeger Publications.

OECD (2005) 'Agricultural Policies in OECD Countries: Monitoring and Evaluation', Paris: Organization for Economic Co-operation and Development, http://www.oecd.org/dataoecd/58/45/35314840.pdf (11 May 2007).

OECD (2006) 'Promoting Pro-Poor Growth: Agriculture', DAC Guidelines and Reference Series; A DAC Reference Document, Paris: Organization for Economic Co-operation and Development.

Omamo, S. W. and Naseem, A. (2005) 'Agricultural Science and Technology Policy for Growth and Poverty Reduction', *ISNAR Discussion Paper*, 3, Washington, D.C.: IFPRI, International Service for National Agricultural Research Division, http://www.ifpri.org/divs/isnar/dp/papers/isnardp03.pdf (11 May 2007).

Otsuka, K. and Place, F. eds, (2002) *Land Tenure and Natural Resource Management: A Comparative Study of Agrarian Communities in Asia and Africa*, Baltimore and London: Johns Hopkins University Press.

Overton, M. (1996) *Agricultural Revolution in England: The Transformation of the Agrarian Economy 1500- 1850*, Cambridge: Cambridge University Press.

Pardey, P. G., Alston, J. M. and Piggott, R. R., eds (2006) *Agricultural R&D in the Developing World: Too Little, Too Late?* Washington, D.C.: International Food Policy Research Institute, http://www.ifpri.org/pubs/books/oc51/oc51.pdf (11 May 2007).

Perkins, J. H. (2003) *Geopolitics and the Green Revolution: Wheat, Genes and the Cold War*, Oxford: Oxford University Press.

Pimbert, M., Thompson, J. and Vorley, B. with Fox, T., Kanji, N. and Tacoli, C. (2003) 'Global Restructuring, Agri-Food Systems and Livelihoods', *Gatekeeper Series*, 100, London: International Institute for Environment and Development, http://www.iied.org/pubs/pdf/full/9166IIED.pdf (11 May 2007).

Poulton, C., Kydd, J. and Dorward, A. (2006) 'Overcoming Market Constraints on Pro-Poor Agricultural Growth in Sub-Saharan Africa', *Development Policy Review,* 24: 243-277.

Pretty, J. N. (2002) *Agri-Culture: Reconnecting People, Land and Nature,* London: Earthscan.

Pretty, J. N., Noble, A. D., Bossio, D., Dixon, J., Hine, R. E., Penning de Vries, F. W. T. and Morison, J. I. L. (2006) 'Resource-Conserving Agriculture Increases Yields in Developing Countries', *Environmental Science and Technology,* 40.4: 1114-1119.

Pritchard, B. (2000) 'The Tangible and Intangible Spaces of Agro-food Capital', paper presented at the International Rural Sociology Association World Congress X, Rio de Janeiro, Brazil, July 2000.

Rao, C. H. H., and Radhakrishna, R. (1999) 'National Food Security: A Policy Perspective for India', in Peter, G.H. and Braun, J. V., eds, *Food Security, Diversification and Resource Management: Re-focusing the Role of Agriculture,* Aldershot, UK: Ashgate Press.

Reardon, T. and Barrett, C. B. (2000) 'Agroindustrialization, Globalization, and International Development: An Overview of Issues, Patterns, and Determinants', *Agricultural Economics,* 23.3: 195–205.

Reardon, T. and Berdegué, J. A. (2002) 'The Rapid Rise of Supermarkets In Latin America: Challenges and Opportunities for Development', editorial overview paper in special issue on Supermarkets, *Development Policy Review,* 20.4: 317-34.

Reardon, T., Timmer, P. C., Barrett, C. and Berdegué, J. (2003) 'The Rise of Supermarket Chains in Africa, Asia and Latin America', *American Journal of Agricultural Economics,* 85: 1140–6.

Richards P. (1989) 'Agriculture as Performance', in Chambers, R., Thrupp, L-A. and Pacey, A., eds, *Farmer Innovation and Agricultural Research,* London: Intermediate Technology Publications.

Richards, P. (1985) *Indigenous Agricultural Revolution: Ecology and Food Production in West Africa,* London: Methuen.

Richards, P. (1993) 'Cultivation: Knowledge or Performance?', in Hobart, M., ed. *An Anthropological Critique of Development: The Growth of Ignorance,* London: Routledge.

Richards, P. (2006) 'The History and Future of African Rice: Food Security and Survival in a West African War Zone', *Afrika Spectrum,* 41.1: 77 – 93.

Rickerl, D., and Francis, C., eds (2004) 'Agroecosystems Analysis', *Monograph Series* No. 43, American Society of Agronomy: Madison, WI.

Rocheleau, D., Thomas-Slayter, B. and Wangari, E., eds (1996) *Feminist Political Ecology: Global Issues and Local Experience,* London: Routledge.

Rockefeller Foundation (2006) 'Africa's Turn: A New Green Revolution for the 21st Century', New York: The Rockefeller Foundation, http://www.rockfound.org/Library/africas_turn.pdf (11 May 2007).

Rondot, P., Biénabe, E. and Collion, M-H. (2004) 'Rural Economic Organizations and Market Restructuring: What Challenges, What Opportunities for Smallholders?' *Regoverning Markets Global Issues Paper,* 4.

Rostow, W. W. (1960) *The Stages of Economic Growth: A Non-Communist Manifesto,* Cambridge: Cambridge University Press.

Ruttan, V. W. (1997) 'Induced Innovation, Evolutionary Theory and Path Dependence: Sources of Technical Change', *The Economic Journal,* 107.444: 1520-1529.

Ruttan, V. W. (1998) *Models of Agricultural Development,* in Eicher, C. K. and Staatz, J. M., eds, *International Agricultural Development,* third edition, Baltimore, MD: Johns Hopkins University Press: 155-162.

Sahn, D. E., Dorosh, P. A. and Younger, S. D. (1997) *Structural Adjustment Reconsidered: Economic Policy and Poverty in* Africa, Cambridge: Cambridge University Press.

Satterthwaite, D. (2005) *The Scale of Urban Change Worldwide 1950-2000 and Its Underpinnings,* London: International Institute for Environment and Development.

Schultz, T. W. (1961) 'Investment in Human Capital', *The American Economic Review,* 1.2: 1-17.

Schultz, T. W. (1964) *Transforming Traditional Agriculture,* New Haven: Yale University Press.

Schultz, T. W. (1968) *Economic Growth and Agriculture,* New York: MacGraw-Hill.

Scoones, I. (2005) *Science, Agriculture and the Politics of Policy: The Case of Biotechnology in India,* New Delhi: Orient Longman.

Scoones, I. and Thompson, J., eds (1994) *Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice,* London: IT Publications.

Scoones, I., Devereux, S. and Haddad, L. (2005) 'Introduction: New Directions for African Agriculture', *IDS Bulletin* 36.2: 1-12, http://www.ids.ac.uk/IDS/KNOTS/PDFs/Ag_Bulletin_Intro.pdf (11 May 2007)

Scott, J. (1998) *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed,* New Haven and London: Yale University Press.

Seshia, S. and Scoones, I. (2003) 'Tracing policy connections: the politics of knowledge in the Green Revolution and biotechnology eras in India', *IDS Working Paper*, 188 (*Biotechnology Policy Series*, 21), Brighton: Institute of Development Studies, http://www.ids.ac.uk/ids/bookshop/wp/wp188.pdf (11 May 2007).

Simon, J. L. (1998) *The Ultimate Resource 2,* Princeton, NJ: Princeton University Press.

Smil, V. (2000) *Feeding the World: A Challenge for the 21st Century,* Cambridge, MA: MIT Press.

Smil, V. (2004) *Enriching the Earth: Fritz Haber, Carl Bosch and the Transformation of World Food Production*. London: MIT Press.

Smit, B. and Wandell, J. (2006) 'Adaptation, Adaptive Capacity and Vulnerability', *Global Environmental Change* 16(3): 282-292.

Spielman, D. (2006) 'Pro-Poor Agricultural Biotechnology: Can the International Research System Deliver the Goods?' *Food Policy,* 32: 189-204.

Sperling, L., Ashby, J. A., Smith, M. E., Weltzien, E. and McGuire, S. (2001) A Framework for Analyzing Participatory Plant Breeding Approaches and Results, *Euphytica,* 122 .3: 439-450.

Stone, G. (2002) 'Both Sides Now: Fallacies in the Genetic-Modification Wars, Implications for Developing Countries, and Anthropological Perspectives', *Current Anthropology,* 43.4: 611-63.

Stone, G. (2005) 'A Science of the Gray: Malthus, Marx, and the Ethics of Studying Crop Biotechnology', in Meskell, L. and Pels, P., eds, *Embedding Ethics: Shifting Boundaries of the Anthropological Profession,* Oxford: Berg.

Stirling, A. (1999) 'Risk at a Turning Point?' *Journal of Environmental Medicine* 1: 119-126.

Stirling, A. (2006) 'Precaution, Foresight and Sustainability: Reflection and Reflexivity in the Governance of Science and Technology', In J. Voß and D. Bauknecht, eds. *Reflexive Governance for Sustainable Development.* Edward Elgar: Cheltenham, UK.

Stringer, L. C., Dougill, A. J., Fraser, E., Hubacek, K., Prell, C. and Reed, M. S. (2006) 'Unpacking "Participation" in the Adaptive Management of Social–Ecological Systems: A Critical Review', *Ecology and Society*, 11.2: 39, http://www.ecologyandsociety.org/vol11/iss2/art39/ (11 May 2007)..

Stumo, M., ed. (2000) *A Food and Agricultural Policy for the 21st Century.* Lincoln, NE: The Organization for Competitive Markets.

Sutherst, W. (2004) 'Global Change and Human Vulnerability to Vector-Borne Diseases', *Clinical Microbiology Reviews*, January: 136–173.

Tacoli, C., ed. (2006) *The Earthscan Reader on Rural Urban Linkages*, London: Earthscan.

Taffesse, A. S. and Ferede, T. (2004) 'The Structure of the Ethiopian Economy – A SAM-based Characterisation. background paper for the Ethiopia Country Economic Memorandum', *World Bank, Ethiopia – A Strategy to Balance and Stimulate Growth, A Country Economic Memorandum*, Report No. 29383-ET, Green Cover, Washington, D.C.: The World Bank.

Tansey, G. and Worsley, T. (1995) *The Food System: A Guide*, London: Earthscan.

Teshome, A. (2006) 'Agriculture, Growth and Poverty Reduction in Ethiopia: Policy Processes Around the New PRSP (PASDEP)', a paper for the Future Agricultures Consortium Workshop, Institute of Development Studies, University of Sussex, UK, 20-22 March 2006.

Thompson, J. (2003) 'Feeding the Future? Agri-food Systems and the Millennium Development Goals', in Satterthwaite, D. ed., *The Millennium Development Goals and Local Processes: Hitting the Target or Missing the Point?*, London: International Institute for Environment and Development, http://www.iied.org/Gov/mdgs/documents/MDG-ch6.pdf (11 May 2007)..

Thompson, J. (2006) 'The Dynamics of Changing Rural Worlds: Balancing Income Generation and Household and Community Food Security in an Era of Growing Risk and Uncertainty', paper presented at the Global Forum on Agricultural Research 3rd Triennial Conference, Reorienting Agricultural Research to Achieve the Millennium Development Goals, 8-11 November, New Delhi, India.

Thompson, J. and Scoones, I. (1994) 'Challenging the Populist Perspective: Rural People's Knowledge, Agricultural Research, and Extension Practice', *Agriculture and Human Values* 11 (2-3): 58-76.

Thompson, P. B. (1992) *The Ethics of Trade and Aid: US Food Policy, Foreign Competition and the Social Contract*, Cambridge: Cambridge University Press.

Tilman, D. (1999) 'Global Environmental Impacts of Agricultural Expansion: The Need for Sustainable and Efficient Practices', *Proceedings of the National Academy of Sciences,* 96.11: 5995-6000.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, B., Dobson, D., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D. and Swackhamer, D. (2001) 'Forecasting Agriculturally Driven Global Environmental Change', *Science,* 292, 13 April: 281-284.

Toulmin, C. and Gueyé, B. (2003) 'Transformations in West African Agriculture and the Role of Family Farms', *Drylands Issue Paper,* 123, London: International Institute for Environment and Development, http://www.iied.org/pubs/pdf/full/9309IIED.pdf (11 May 2007)..

Trewavas, A. J. (2001) 'The Population/Biodiversity Paradox: Agricultural Efficiency to Save Wilderness', *Plant Physiology,* 125: 174-179.

Tripp, R. with Longley, C., Mango, C., Mango, N., Nindo, W., Piyadasa, V. H., Richards, M., Suazo, L. and Wijeratne, M. (2006) *Self-Sufficient Agriculture: Labour and Knowledge in Small-Scale Farming,* London: Earthscan.

Tripp, R., Wijeratne, M. and Piyadasa, V. H. (2005) 'What Should We Expect from Farmer Field Schools? A Case Study from Sri Lanka', *World Development,* 33.10: 1705-1720.

UN Millennium Project (2005a) *Halving Hunger: It Can be Done. UN Millennium Task Force Report on Hunger*. London: Earthscan, http://www.unmillenniumproject.org/documents/Hunger-lowres-complete.pdf (11 May 2007).

UN Millennium Project (2005b) *Innovation: Applying Knowledge in Development. UN Millennium Task Force Report on Science, Technology and Innovation,* London: Earthscan.

UNAIDS (2006) *Report on the Global AIDS Epidemic,* Geneva: UNAIDS, http://www.unaids.org/en/HIV_data/2006GlobalReport/default.asp (11 May 2007)..

UN-Energy (2007) *Sustainable Bioenergy: A Framework for Decision-Makers,* New York: UN-Energy, http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf (11 May 2007).

Uphoff, N. (2007) 'Envisioning Post-Modern Agriculture', draft paper, Ithaca, NY: Cornell International Institute for Food, Agriculture and Development, http://www.wassan.org/sri/documents/Post_Modern_Agriculture_March07.pdf (11 May 2007).

Uphoff, N., Ball, A. S., Fernandes, E., Herren, H., Husson, O., Laing, M., Palm, M., Pretty, J. and Sanchez, P. (2006) *Biological Approaches to Sustainable Soil Systems,* Boca Raton, FL: CRC Press.

Vogel, S. J. (1994) 'Structural Changes in Agriculture: Production Linkages and Agricultural Demand-Led Industrialization', *Oxford Economic Papers,* 46.1: 136-156.

Vorley, B. (2002) *Sustaining Agriculture: Policy, Governance, and the Future of Family-Based Farming,* London: International Institute for Environment and Development, http://www.poptel.org.uk/iied////sarl/pubs/exec_summ/9175.html (11 May 2007).

Vorley, B. (2003) *Food, Inc.: Corporate Concentration from Farm to Consumer,* London: UK Food Group, http://www.ukfg.org.uk/docs/UKFG-Foodinc-Nov03.pdf (11 May 2007).

Vorley, B., Fearne, A. and Ray, D. eds (2007) *Regoverning Markets: A Place for Small-Scale Producers in Modern Agrifood Chains?* Co-published with the IIED (International Institute for Environment and Development) and sponsored by the DFID (Department for International Development). Aldershot, UK: Gower Sustainable Food Chain Series.

Wade, R. H. (2003) 'What Strategies are Viable for Developing Countries Today? The World Trade Organization and the Shrinking of "Development Space"', *Review of International Political Economy,* 10.4: 621–644.

Walker, B.H., Holling, C.S., Carpenter, S.R., and Kinzig, A.P. (2004) 'Resilience, Adaptability, and Transformability', *Ecology and Society* 9(2): 5. http://www.ecologyandsociety.org/vol9/iss2/art5/. (11 May 2007)

Walters, C. (1986) *Adaptive Management of Renewable Resources,* Macmillan: New York.

Warren, D. M., Slikkerveer, L. J., and Brokensha, D., eds (1995) *The Cultural Dimensions of Development: Indigenous Knowledge Systems,* London: Intermediate Technology Publications.

Windfuhr, M. and Jonsén, J. (2005) 'Food Sovereignty: Towards Democracy in Localized Food Systems', Rugby: ITDG Publishing, http://ukabc.org/foodsovereignty_itdg_fian_print.pdf (11 May 2007).Winterfeldt, D. von and Edwards, W. (1986). *Decision Analysis and Behavioural Research,* Cambridge: Cambridge University Press.

Wordie, J. R. (1983) 'The Chronology of English Enclosure 1500-1914', *Economic History Review, Series 2,* 36.4: 483-505.

World Bank (1982) *World Development Report 1982,* Washington, D.C.: The World Bank.

World Bank (2002) *Sustainable Development in a Dynamic World: Transforming Institutions, Growth and Quality of Life. World Development Report 2003,* New York: The World Bank and Oxford University Press.

World Bank (2005) *Agricultural Growth and the Poor: An Agenda for Development,* Directions in Development, Washington, D.C.: The World Bank.

World Bank (2006) *06 World Development Indicators,* Washington, D.C.: The World Bank, http://devdata.worldbank.org/wdi2006/contents/home.htm (11 May 2007).World Bank (2007) *World Development Report 2008: Agriculture for Development,* draft version, Washington, D.C.: The World Bank, http://siteresources.worldbank.org/EXTWDR2008/Resources/Fulltext_01Apr.pdf (11 May 2007).Wynne, B. (1992) 'Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm', *Global Environmental Change* 2(2): 111-127.

World Bank (2007) *World Development Report 2008: Agriculture for Development* (Draft version), Washington, D.C.: The World Bank.

Yoxen, E. (1983) *The Gene Business: Who Should Control Biotechnology? London: Pan Books.*