TOPIC GUIDE:
Agricultural Productivity

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Contents

List of Boxes

List of Tables

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SECTION 1

Introduction

As the recent world food crisis has demonstrated, meeting the food needs of a growing world population, projected to reach over 9 billion people by 2050, is going to be a challenge. The challenge is especially daunting for many African and South Asian countries that face the highest population growth rates and which already have some of the severest per capita land constraints.

There are two ways to increase agricultural production. One is to use more inputs, like land, labour, water and fertiliser. The other is to adopt improved technologies and management practices that raise the productivity of the inputs that are used. For example, improved crop varieties can improve the yield response to fertilisers, improved water management practices can provide greater output per drop of water, and machines can increase the amount of work that a labourer can complete in a day. People have relied on the first source of growth – use of more inputs – for most of history, and this is still possible in some land-abundant countries in Africa and Latin America. However, most countries are already using all their available land and water, and they use other inputs to the point where additional application is not widely profitable. To meet the growing demand for food, substantial increases in the productivity of the inputs that are already used in agriculture will be required.

Raising productivity is also important for farmers. For commercial farmers this enables them to compete better in the market on cost and quality, and to increase their incomes. For subsistence-orientated farmers, this is how they can grow more food for their own consumption from their limited bundle of resources. Raising agricultural productivity also makes important contributions to a country's development. It enables a greater supply of food and other raw materials to be produced at lower unit costs, frees up labour for use in other production sectors, and saves on food imports. A dynamic farm sector also provides strong demand linkages to the non-farm sector, including agro-industry.

Not all ways of increasing agricultural productivity are equally good. Given the huge diversity of farming conditions that exists, improved technologies and farming practices must be selected and adapted to local conditions. Even then, they may lead to very different social, economic and environmental outcomes, even for comparable levels of increase in agricultural production. Not only must agricultural production be increased, but the contemporary development agenda calls for this to be done in ways that are environmentally sustainable, that contribute to reducing poverty, food insecurity and malnutrition, that create productive employment, that empower women, and that lead to more climate resilient farm and rural economies. All this is to be achieved whilst obtaining rates of return to public investments in agriculture that are competitive with investments in other sectors.

The means by which improved technologies and farming practices are developed and disseminated also vary, some being more readily provided by private sector firms (e.g. seed and engineering firms), whereas others depend more on the public sector (e.g. access to technology and markets via rural roads). Public policy also plays an important role in guiding technology discovery and adoption processes (e.g. through public funding and laws about intellectual property rights), and helps determine whether farmers will find it attractive to adopt technologies and farming practices that are win-win in terms of their desired social, economic and environmental outcomes. Public interventions are especially important for raising the productivity of poor farmers and women farmers.

Paper outline

This Topic Guide provides an overview of the ways in which agricultural productivity has been successfully raised in developing countries, and of the social, economic and environmental consequences. It draws on the available evidence base, and highlights areas where important knowledge gaps still remain.

The Topic Guide begins in Section 2 by defining key concepts and measurement approaches related to agricultural productivity, then in Section 3 provides a global review of past patterns of production growth and the contributions of productivity growth. Section 4 explores the sources of productivity growth, including the role of agricultural research in developing new technologies and management practices, and the social and economic constraints that may prevent their widespread adoption. Section 5 reviews the evidence on how improved technologies impact on the poor, both within the areas where the technologies are adopted and through spillover benefits or costs that may affect wider populations. Section 6 examines the impact of new technologies and farming practices on the environment, while section 7 addresses the specific problem of restoring prior levels of agricultural productivity in conflict areas. Throughout, special attention is given to the implications for women and poor farmers, and the types of policies that can facilitate better productivity, economic, social and environmental outcomes. Section 8 provides some concluding comments.

SECTION 2

Key concepts for measuring agricultural productivity

The most commonly used measures of agricultural productivity are partial measures that capture the returns to individual inputs. For example, yield (output/land area), is a measure of the average productivity of land. Average labour productivity (output/number workers) is a good proxy for per capita agricultural income and, at low levels, also correlates negatively with poverty.

Although useful, partial measures of productivity are not reliable measures of economic efficiency because they do not take account of the use of other inputs or their costs. For example, land productivity can be increased by applying more labour, and this may lead to lower labour productivity. In areas with surplus land, labour productivity can be increased by farming more land, but land productivity may remain stagnant or even fall if the expansion is onto more marginal land. Moreover, both land and labour productivity are affected by the use of other farm inputs like fertilisers and tractors, which have their own economic costs.

A better measure of economic efficiency is total factor productivity (TFP), sometimes referred to as multifactor productivity. This is calculated as the ratio of total output to total input, and measures the average productivity of all the inputs used. All inputs need to be included, otherwise the measure of TFP obtained will be biased upwards by the returns to missing inputs.

Measuring partial measures of productivity for the same crop or livestock is relatively easy, given there is a single output and a single input which can be measured in quantity or value terms. However, when the outputs of different crops and livestock have to be aggregated these then need to be added in value terms, which requires the selection of suitable price indices. The challenge is even greater when measuring TFP, since not only the value of outputs but also that of all the inputs has to be valued and added. The methods used in these calculations, especially the choice of indices, have an important bearing on the results, and have been discussed at length in the economics literature (Alston et al, 1998, provide a comprehensive discussion).

Increases in agricultural productivity, especially TFP, not only increase the returns to existing inputs, but also prevent diminishing returns from setting in when additional inputs are used to increase production. Diminishing returns imply that the cost of producing a unit of output (e.g. a kilogram of rice) increases, making agricultural products, including food, more expensive to produce.

Increases in factor productivity can arise in two ways. One is from improved technologies that shift the production function upwards (i.e. give more output for the same level of inputs). New crop varieties, for example, may give higher yields than older varieties, even when input use is held constant. The other way to raise productivity arises when farmers are not fully exploiting the potential of their current technologies. For example, their management practices may be sub-optimal, and adoption of improved practices might lead to greater output even with the same or lower levels of input use. This source of productivity gain is called an ‘efficiency’ gain in the literature. One example of this potential efficiency gain is the observed difference between the yields of ‘best’ farmers versus the average farmer operating under similar conditions.

Some technology shifts are biased towards increasing the productivity of some inputs more than others, e.g. improved seeds improve the productivity of land more than that of labour, while mechanisation improves the productivity of labour more than that of land. Some shifts are more neutral and increase the productivity of several inputs at the same time, e.g. irrigation. According to the ‘induced innovation’ theory, these input biases are important in determining the types of technologies that are appropriate for different economic situations. For example, land-scarce countries with abundant labour will tend to adopt technologies that are biased towards raising land productivity, while countries with plenty of land relative to labour will tend to adopt technologies biased towards raising labour productivity. These patterns have been amply demonstrated through studies of agricultural productivity growth over time for different types of countries – the classic study is Hayami and Ruttan (1971; 1985). Similar patterns are found in the more recent ‘directed technology change’ literature (Acemoglu, 2002). Highly similar arguments hold for individual farms.

SECTION 3

What is the record on productivity growth?

At the global level, agricultural production has grown much faster than the population in recent decades, leading to a steady increase in per capita agricultural output (including food). In a dramatic break with historical patterns, expansion of the total cropped area in most parts of the world has played a remarkably small role in increasing agricultural production since the Second World War, to the point that growth in the global extent of cropland has virtually stagnated since the 1960s (Hazell & Wood, 2008).

As a result of this unprecedented growth in land productivity, the world now produces more than enough food to feed the entire population to minimum UN standards if it were distributed more equitably. Even more remarkably, this surplus has been achieved despite the diversion of considerable land, labour and other rural resources to the production of higher-value foods (meat, milk, fruits, vegetables, etc.) to meet the changing food demands of growing, more urbanised, and more affluent populations. This includes the additional cereals and oil crops needed as feed grains in intensive livestock systems and inland aquaculture, and for biofuels production.

This favourable global perspective masks some important regional variation. While most parts of the developing world have successfully and continuously increased their agricultural output per capita since the 1960s, sub-Saharan Africa has experienced stagnant, even declining per capita output (ibid).

What is less certain is how much of this global increase in land productivity can be attributed to productivity growth, and how much can be attributed to greater use of inputs other than land. Also, within productivity growth, how much can be attributed to technologies that have shifted the production frontier, and how much to efficiency gains from improved management practices? These issues have been probed at some length in the literature using various measures of productivity.

A good example is a study by Fuglie (2010) who analysed the growth in the productivity of world agriculture over the period 1961-2007. He defined total inputs to include land and structures, labour, livestock and feed, machinery and energy, and chemicals and seeds. Table 1 shows the key results.

Period	Output	Inputs	TFP	Output per worker	Output per hectare	Grain yield per hectare
1961-1969	2.81	2.31	0.49	0.96	2.39	2.84
1970-1989	2.18	1.40	0.77	1.22	1.97	2.31
1990-2007	2.04	0.59	1.45	1.40	1.90	1.35
1961-2007	2.23	1.24	0.99	1.25	2.01	2.02

Table 1 Productivity indicators for world agriculture, 1961-2007: average annual growth rate by period (%) (Fuglie, 2010)

Output grew by 2.23% per annum on average over the entire 1961-2007 period, and this was achieved through a 1.24% per annum growth in total inputs and a 0.99% per annum growth in TFP, i.e. productivity growth accounted for 45% of the total growth in output, while the increased use of inputs including land accounted for 55%. Looking at sub-periods, output growth slowed progressively from 2.81% per annum during 1961-69, to 2.18% per annum during 1970-89, then to 2.04% per annum during 1990-2007. This slowdown was driven by a sharp and consistent drop in the growth of total inputs used in agriculture; the slowdown would have been even greater had there not also been a progressive growth in TFP. During 1990-2007, TFP growth accounted for 71% of the growth in output, compared to 17% during 1961-69. This clearly illustrates the increasing dependence of the global food supply on gains in agricultural productivity.

The partial measures of productivity reported in Table 1 show that labour productivity improved over the entire period, whereas land productivity fell. The technical changes underlying the growth in TFP were seemingly biased towards labour rather than land.

These kinds of results are not always robust, and by comparing results from alternative estimates with the same data sets (Rezek et al, 2011; Headey et al, 2010), one finds that results are sensitive to the length of the time series used, the sample of countries included, and the technique used in calculating and decomposing TFP growth. More robust results tend to hold for aggregates of countries rather than individual countries, and for long rather than short time periods.

SECTION 4

What drives growth in agricultural productivity growth?

The primary driver of productivity growth is new technologies and better ways of doing things, so understanding the sources and diffusion of new technologies and knowledge is fundamental. However, new technologies and knowledge only make a difference when they are adopted by farmers and rural communities; therefore, understanding the conditions under which adoption occurs is also crucial.

Sources of new technologies

There are multiple sources of new technologies and knowledge. Indigenous knowledge and farmer experimentation have historically been an important source of technological change, and accounted for slow but steady increases in productivity over generations. However, the more dramatic breakthroughs that were needed to keep pace with rapidly growing and urbanising populations have come from the application of modern science by agricultural research organisations. The development of English wheat yields is typical of what has happened in many agricultural systems around the world (see Box 1). This has led to a constant stream of new technologies that has enabled sustained and unprecedented rates of growth in agricultural productivity over the past 75 years.

Box 1 Development of English wheat yields

Between 1300 and 1700, English wheat yields increased by 50% as a result of farmer innovations, but were still only about 0.5 t/ha in 1700 (Grigg, 1984). They began to accelerate a little thereafter, driven by such developments as: Jethro Tull's seed drill which, by planting the crop in straight rows, permitted inter-row tillage; the Rotherham mould board plough, which permitted complete inversion of the soil and better weed control; the incorporation of legumes and livestock into improved rotations; the first development of artificial fertilisers in the 1840s (Deane, 1965).

By the 1850s, average wheat yields had risen to 1.1 t/ha, and to 2 t/ha by 1909-1913, a period which saw the more widespread adoption of artificial fertilisers. They remained relatively static until the late 1930s, after which they increased exponentially, fuelled by modern plant breeding, improved agronomy, and the development of improved inorganic fertilisers and modern pesticides. By the 1980s, average wheat yields had reached nearly 6 t/ha. Thus in the space of 40 years, wheat yields increased by 3.1 t/ha, or by more than the increase achieved in the whole of the preceding six and one-half centuries. Today English wheat yields average 7.7 t/ha.

The private sector has long been involved in developing modern inputs such as machines, fertilisers, pesticides, and hybrid seeds that can be sold to farmers on a repeat basis. However, many of the technologies and improved husbandry practices needed from agricultural research cannot be privatised in this way, and hence have had to be developed by public sector institutions. Recent developments in intellectual property rights and biosciences have enabled the private sector to increase the range of proprietary products it can produce, and hence increase its role in agricultural research. It now accounts for about

20% of global research and development (R&D) spending, but is mainly concentrated in the OECD countries, Brazil, China, and India (ASTI, 2012).

In 2008, developing countries spent US$15.6 billion (in inflation-adjusted, purchasing power parity (PPP) dollars) on public agricultural research, compared to US$16.1 billion in developed countries. Three developing countries (Brazil, China and India) accounted for half of the total developing country public spending, while sub-Saharan Africa accounted for a meagre 5% (ibid). Another US$500 million was spent on international agricultural research conducted by the international research centres of the Consultative Group on International Agricultural Research (CGIAR).

Evidence on productivity impacts

Public investments in research of these magnitudes have led to a host of studies to determine whether the investments are worthwhile from a productivity perspective.

Difficulties arise in measuring productivity impacts because of selectivity biases that make direct comparison of adopters with non-adopters suspect, of partial adoption that requires plot-level rather than household-level data, of weather variability that requires time-series data, and of more generally simply collecting reliable quantitative data on yields at the plot or farm level.

In many cases there are problems defining what the technology ‘treatment’ (in evaluation parlance) actually comprises. Unlike single-dimensioned treatments in, say, drug-evaluation trials, farmers typically face multi-dimensioned choices about combining different components of a technology package (e.g. seeds, fertiliser, and planting dates and densities) and may (or are even encouraged to) adapt the package to their own farm-level conditions. Lack of a standard package then makes evaluations much more difficult. A good example is the adoption of key components of the System of Rice Intensification (SRI) described in (see Box 6). Moreover, some technologies are not expected to raise yields every year, but only reduce pest or drought damage in bad years; this can be difficult to observe on any planned basis.

New methods such as randomised trials and econometric ways of pairing adopting and non-adopting farms are helping to bring greater rigour to research, especially in controlling for selectivity biases. However, they are expensive and difficult to scale up, and do not solve many of the problems listed above. A substantial body of secondary or circumstantial evidence should not be ignored, such as available results from on-research stations and on-farm trials, and from direct elicitation from farmers about perceived yield differences under a range of weather conditions.

These problems notwithstanding, evidence from the Green Revolution era is pretty conclusive on linking R&D to increases in land productivity. Even though the increased use of irrigation and fertiliser was important in explaining yield growth, the release of high-yielding crop varieties that responded well to favourable growing environments led to much larger total impacts on yields. In a definitive study, Evenson and Gollin (2003) provide a comprehensive analysis of the global evidence on the impact of crop-genetic improvement over the period 1965-1998 for all the major food staple crops. They also break down CGIAR’s contributions and find very large impacts, especially for rice, wheat and maize.

In another study covering much the same period, Alston et al (2000) undertook a widely cited meta-analysis of 1,852 published project evaluations reporting rates of return to research investments. They found that the average annual rate of return was 65%, but that there was considerable variation across studies with a range of -100% to 910%. The average rate of return was higher for developed (98%) than developing countries (60%). It was also higher for Asia (78%) than for sub-Saharan Africa (50%), and for Latin America and the Caribbean (53%). In a recent update of this study, Rao, Hurley and Pardey (2012) expand the set of evaluations to 2,186, published between 1958-2011. The average annual rate of return was found to be 74.3%, with a median value of 43% and a range of -47.5% to an incredible 5,645% per year.

There are questions about whether these estimates are biased upwards because only evaluations from more successful projects might have been undertaken and published. Moreover, there are problems in the way internal rates of return are calculated for R&D projects that have long gestation periods; when these problems are corrected, the estimated rates of return can be substantially less, though still attractive (ibid).

Other more recent evidence from CGIAR impact studies is assessed by Renkow and Byerlee (2010). While the impacts are not as dramatic in scale as those in earlier periods, there are several rigorous studies showing favourable impacts on productivity.

Difficulties and robust findings

One difficulty of relying on project-level studies is that only successfully completed studies are likely to be assessed. Research is inherently a risky venture, many research investments may have failed or not been completed, and the cost of these investments really ought to be included. One way this is done is through studies that evaluate the impact of entire research portfolios, such as the total public spending on agricultural research by a national government. These studies invariably use time-series data and econometric methods to estimate changes in TFP in agriculture and to measure the contributions to change of various driving factors, including spending on agricultural R&D. Analysts must contend with a number of statistical problems (e.g. interdependencies between explanatory and dependent variables, high correlations between variables over time, missing explanatory variables, and possible lag structures). In addition, the ability to make appropriate adjustments to avoid misleading results is constrained by the scope and quality of the available data set. Despite these limitations, a few robust findings seem to stand out from across studies.

The **first finding** is that aggregate research spending does seem to yield consistently high returns. Evenson et al (1999) identified 10 *ex post* studies of the returns to aggregate research programmes in South Asia. Despite some differences in methods of analysis and time periods covered, all the studies show internal rates of return to research ranging from 36% to 143%, much higher than any reasonable discount rate. In a much-cited but possibly less reliable study (because it has limited time-series observations), Thirtle et al (2003) estimate the rate of return to total R&D spending in 44 countries and calculate weighted averages by continent. They obtain a rate of return of 22% for Africa (north and sub-Saharan Africa), 31% for Asia, but -6% for Latin America. The negative return for Latin America is attributable to Brazil, which dominates the weighted average and has a -6% return.[1]

In a similar type of study, Fan and colleagues at the International Food Policy Research Institute (IFPRI) obtained benefit/cost ratios for different items of public rural spending, including agricultural R&D, in India and China (Fan & Rao, 2008). Agricultural R&D spending has large benefit/cost ratios in both countries, and dominates all other forms of public spending in rural areas (see Table 2).

[1] The authors attribute the negative result for Latin America to the fact that large countries like Brazil have reached a stage in their economic development where yield-increasing innovations are no longer such a driving force in their development process, and that shedding labour to other sectors is more important for productivity growth.

Expenditure variable	India 1970-93	China 1970-97
R&D	13.45	6.75
Irrigation	1.36	1.45
Roads	5.31	1.69
Education	1.39	2.17
Power	0.26	0.82
Soil & water	0.96	NI
Rural development	1.09	NI
Health	0.84	NI
Rural telephone	NI	1.63

Note: *NI means not included*

Table 2 Productivity returns in agriculture from various items of public rural spending, benefit/cost ratios, for India and China (Fan & Rao, 2008)

Another consistent finding from studies is the long lead times that arise between the launching of new agricultural research projects and their eventual impacts in farmers' fields. These lead times can be as long as 10-20 years for some types of crop and livestock improvement research (Alston et al, 2000), but can be much shorter for applied research on improved farming practices. Investments in agricultural research may have powerful productivity impacts, but many are not quick fixes and need to be planned well ahead. Spending on them also needs to be sustained over their full life cycles.

Adoption of new technologies

What drives the uptake of new technologies and knowledge? Some technologies can be adopted by individual farmers (e.g. new seeds), but some need to be taken up in a collective way by groups of farmers or even whole communities (e.g. surface irrigation and watershed development, and the improvement of communal forests and grazing areas).

Adoption at the community level

Population pressure on a fixed land base has proven an important driver of technology adoption at community and regional levels. There are two contrasting schools of thought about this relationship. Malthus, writing in 18th century England, observed that population growth led to expansion of the cropped area into ever more marginal lands, resulting in declining labour productivity and per capita output. He postulated that this process of impoverishment would continue until per capita output declined to subsistence levels, below which population growth was unsustainable. Malthus assumed that there would be little technological change in farming, hence little increase in productivity.

In a contrasting and more optimistic view, Boserup (1965) argues that, as population pressure grows and labour becomes less costly relative to land, a process of 'induced innovation' occurs whereby communities invest in agricultural intensification and in improving their natural resources. For example, in many Asian societies, growing population pressure has led to labour-intensive investments in the terracing and levelling of cropland, to the construction of elaborate irrigation systems, and to the use of composting and manures.

The induced innovation theory predicts increases in agricultural output and land productivity, enabling growing populations to feed themselves. However, it does not necessarily predict that output per worker (or average labour productivity) will also increase. This will depend on the speed and type of the induced technological change. If average output per worker continues to decline, the induced innovation model can also lead to the same state of impoverishment predicted by Malthus – it will just take longer to get there. Geertz (1963) documented such a process in Java and coined the term ‘agricultural involution’. Moreover, if technological change can raise labour productivity even as more workers are absorbed into the system, then per capita incomes will rise on average, and a process of sustainable economic development may be launched.

The empirical evidence on these issues is mixed. A much-cited study of Machakos district in the Kenyan highlands with the provocative title *More People, Less Erosion* (Tiffen et al, 1994) provided a striking example of induced innovation and raised hopes within the development community about the prospects for many degraded and impoverished regions. However, there are reasons to believe that Machakos owes much of its success to a favourable location with easy access to markets and non-farm jobs in Nairobi.

Community surveys conducted by IFPRI researchers in poor hillside areas in Ethiopia, Uganda, and Honduras found weak or negative relationships between population density and agricultural productivity (Pender et al, 2001; 2006). According to this research, **the key to successful community pathways out of poverty lies with improved access to markets, especially for higher-value products, and access to new technologies that can increase land and labour productivity faster than population growth.** Goldman and Smith (1995) also conclude that market access is far more important than population growth in driving patterns of intensification, based on studies in Nigeria and India.

Communities vary widely in their ability to organise and sustain effective collective action – whether it be managing community-owned resources or adopting community-level technologies. This has led to a body of research trying to understand the determinants of this variation. Over a lifetime of research, Nobel Laureate Elinor Ostrom has shown that success is conditioned on a range of physical, social, and institutional factors. On the other hand, attempts by governments to manage collective action themselves by nationalising forests and rangelands, and through top-down watershed development programmes (e.g. India), have met with limited success. **The more recent trend has been towards greater devolution of the management (if not the ownership) of common properties to local communities, and the empowerment of local institutions to manage them.**

There has been a veritable explosion in the formation of community-based organisations in recent years, driven largely by environmental- and development-orientated non-governmental organisations (NGOs) that have become active at the grassroots level. Community organisations have also been promoted by some donors, such as the International Fund for Agricultural Development (IFAD) and the World Bank, as a way of funnelling investment resources directly to local communities which can invest in micro-projects of their own choice (Binswanger-Mkhizi et al, 2010).

The primary evidence base for drawing conclusions about the effectiveness of community organisations is comparative studies. These are mostly qualitative studies and, while they provide a lot of depth about what is happening within communities, they lack rigour in making comparisons across communities. At best, one finds studies, such as the IFPRI study based on a survey of a large number of communities in Ethiopia, Uganda, and Honduras (Pender et al, 2001; 2006), that use regression analysis to explain the difference between villages; however, they are limited by difficulties in capturing relevant explanatory variables. The ideal study would be based on in-depth studies of large numbers of communities over time, but such data sets rarely exist.

Nevertheless, several useful insights have emerged. One is that community organisations are more likely to succeed when all the key stakeholders are involved. In some cases, involving only one group of farmers within the community may be necessary – as, for example, in contouring part of the landscape. In other cases, a whole village may need to be involved, as in watershed development projects. Sometimes it will be necessary to embrace several villages, for example in the management of open rangelands which may be shared by a number of local communities or even distant tribes.

Another finding is that, to avoid the capture of benefits by community elites and to be able to resolve local disputes, broad representation is needed in the governance of community organisations (Uphoff, 2001). This is particularly important if poor and women farmers are to be empowered within such organisations (Meinzen-Dick et al, 2011).

The start up and early development of local organisations can be particularly fraught because of a lack of leadership and technical and administrative skills in the community. There is some evidence that technical training and leadership support from outside agencies like NGOs can be crucial in the early stages of organisational development; however, this needs to be undertaken with an exit strategy in mind.

Adoption at the farm level

There is typically a lot of diversity in farm-level adoption decisions. Typically there are lead farmers who take the plunge, and then others follow when they have observed a favourable outcome. There are also many constraints to adoption, particularly in the short term, and which impact differently on individual farmers.

Adoption rates for a region typically follow an ‘S’ shaped growth curve over time, starting off slowly with a few innovators, then accelerating as more and more farmers join in, and then slowing again as only those who are unlikely to adopt remain. The speed of adoption and the final rate of adoption achieved (sometimes called the ceiling rate of adoption) depend to a large degree on the agro-climatic suitability of the technology and its level of profitability. The high-yielding rice varieties of the Green Revolution spread very quickly across Asia, from 0% of the rice area in 1965 to 40% by 1980, and about 80% by 2000. The adoption of the high-yielding wheat varieties was even faster, reaching about 90% of the wheat area by 2000 (Gollin et al, 2005). On the other hand, the adoption of improved crop varieties has been much slower and less complete in Africa (Evenson & Gollin, 2003), as has the adoption of many improved natural resource-management practices around the world.

Given the importance of adoption to the success of agricultural R&D, a huge number of studies have been carried out on the determinants of technology adoption among farming populations (for reviews see Adato & Meinzen-Dick, 2007; Doss, 2006; Feder et al, 1985; Jack, 2013; Lipton, 1989). Drawing on a large body of empirical studies, these have identified a number of frequently occurring factors that correlate with adoption rates (these are listed in Box 2).

Box 2 Common determinants of technology adoption by farmers

Characteristics of the technology:

i. **Appropriateness of new technologies** in terms of their fit with a farm's agro-ecological conditions, own consumption requirements (e.g. the storability, cooking and taste traits of new crop varieties), and available resource endowments (e.g. some new technologies or crops require lots of labour for weeding and harvesting at already busy times of the year, and this may be difficult for non-mechanised farmers to supply).

Access issues:

i. **Access to knowledge about new technologies**.
ii. **Access to market opportunities** to warrant investment beyond own consumption needs.
iii. **Access to and affordability of the necessary purchased inputs** like seeds, fertilisers and pesticides.
iv. **Available financial resources**, such as own savings and access to credit or non-farm sources of income. This is particularly important for lumpy investments where a threshold level of capital is required.
v. **The riskiness of new technologies**. Production and market risks can deter adoption of improved seeds and fertiliser use, particularly if they have to be purchased with credit. For longer-term investments in resource improvements there are additional risks such as the loss of rights over land, loss of assets due to theft, civil strife or natural catastrophes, changes in health, and changes in government policies.
vi. **The property rights that farmers have over natural resources** can be important in determining whether they are willing to make investments that improve the long-term productivity of those resources (e.g. planting trees and contouring land). Secure property rights can also be important for obtaining credit in order to make long-term investments.
vii. **Ability to organise effective collective action** for some types of productivity-enhancing investments that have to be undertaken jointly by neighbouring farmers or whole communities.

Household characteristics:

i. **Age of household**. Younger households typically invest more in building up farm assets and are more likely to innovate, adopt new technologies and make long-term improvements to natural resources. Older households tend to invest less, and may scale down their farm assets through disposal or depreciation.
ii. **The education level and literacy level of household heads** is widely associated with greater innovation and investment in farming, as is farmer training and extension.
iii. **Farm size**. Large- and medium-sized farms have often been the early innovators with smaller farms catching up later (Lipton, 1989). Large farms are also more likely to adopt labour saving technologies like tractors (Pinstrup-Andersen, 1982). That said, there is plenty of recent evidence to show that many small commercially orientated farms can be technologically dynamic, particularly in producing high-value commodities for the market.
iv. **Gender** is also important, but often in a perverse way, because women farmers are often discriminated against in access to new knowledge, technologies, property rights and credit (Peterman et al, 2010).

Many of these factors are particularly constraining for women and poor farmers. They are often the least likely to have access to information about new technologies, modern inputs, credit, secure land rights, and mechanisation. Based on a review of 24 empirical studies (mostly from Africa), Peterman et al (ibid) conclude that, given equal access, there is no significant difference between adoption rates of modern technologies and inputs for men and women farmers. Hence, for productivity as well as equity reasons, there is a strong case for improving women's access to the key requisites for technology adoption (Quisumbing, 1995). Udry et al (1995) estimate that for Sub-Saharan Africa (SSA), agricultural production could increase by between 10% and 20% if women had equal access, a very significant 'gender dividend'.

Policies to promote technology adoption

Many constraints to technology adoption reflect underlying market failures that lead to sub-optimal levels of technology uptake and productivity growth from an aggregate economic perspective (Jack, 2013). Market failures also make it harder for many poor farmers and women farmers to adopt, constraining the potential of agricultural R&D investments to contribute to social and environmental goals (such as reducing poverty and land degradation, and achieving gender equity). For these reasons, most countries have long intervened to promote the development and adoption of productivity-enhancing technologies in agriculture.

During the Green Revolution era, many governments used a top-down approach that included public provision of agricultural research and extension, shoring up farm credit systems, subsidising and distributing key inputs (especially fertiliser, power, and water), and intervening in markets to ensure farmers received adequate prices each year to make new technologies profitable. Box 3 describes the Indian experience in promoting the Green Revolution.

Research by Dorward and colleagues at the School of Oriental and African Studies has shown that these kinds of interventions can be quite effective at early stages of agrarian development. In these stages, value chains are still poorly developed, and the demand for key inputs like improved seeds and fertilisers is still too low and spatially thin for private delivery systems to work adequately (Dorward et al, 2005; 2009). However, as value chains develop, these kinds of interventions can quickly become costly and inefficient, and need to be phased out once they have served their initial purposes.

Box 3 India's Green Revolution Agenda (Hazell, 2009)

Immediately after independence in 1947, the Indian government made agricultural development its top priority. Realising that India would have to develop the physical and scientific infrastructure necessary to support modern agriculture, Prime Minister Jawaharlal Nehru and his government poured resources into the effort, allocating 31% of the country's budget to agriculture and irrigation. Massive irrigation projects, power plants, state agricultural universities, national agricultural research systems, and fertiliser plants sprang up across India. These steps were accompanied by land reform designed to create a more equitable distribution of land.

In the mid-1960s, drought and population growth made India more dependent on US food aid, despite its own agricultural potential. Following a study by the Ford Foundation in the early 1960s, the Indian government set up the Intensive Agricultural District Programme to invest heavily in agricultural extension and distribution of subsidised inputs. The government also established the Food Corporation of India, which bought excess production at a guaranteed price in order to provide stability to farmers. The government also took an active role in coordinating interventions from donors and development partners, who financed agricultural extension as well as research and development. All of this came on top of India's considerable existing infrastructure, including roads and irrigation systems – the Indian government coordinated interventions all along the market chain to enable the entire agricultural system to function.

As a result, most rural small-scale farmers could profitably obtain and use inputs such as high-yield seeds, fertilisers, irrigation, and credit. Despite heavy government involvement in the production, dissemination, and adoption of these inputs, the private sector also played a key role. The dual private and public marketing system actually helped improve the efficient distribution of inputs to farmers. The success of India's Green Revolution arose from the combination of subsidised inputs, public investments in infrastructure (roads, power, and irrigation), research and extension, and, later, marketing policy interventions that assured farmers' access to market outlets at stable prices.

Many countries cut back or phased out these interventions after the mid-1980s as part of market liberalisation programmes. This has led to a greater role for private sector and NGO players and the emergence of more innovative and diverse types of policy interventions. Some of the more successful approaches are summarised in

Box 4.

While there has been much promising innovation and many demonstrated successes, a key question remains: *will these new approaches be sufficient to solve the adoption problem for large numbers of small farms, especially poor and women farmers, or will new technologies be mainly accessible to larger commercial farms and to those small farms who can successfully organise to access modern value chains?* This is clearly an ongoing agenda and pilot innovations need to be backed up by rigorous evaluations showing their impact on key target groups. There is also much to be learned about how and where to scale up successful pilots when they arise. Scaling up requires going beyond measuring success and paying attention to the causal factors underlying success. It also requires an ability to identify and even map other places where the same conditions for success might exist. At present there is little guidance on the kinds of data and analysis that would be required to enable such inferences.

For reaching women farmers, Quisumbing and Pandolfelli (2010) provide a useful review of the evidence base on best practices. They also point out **the need to recognise that not all women are the same, and that large variations in their age, marital status, education level and size of holding require more specific targeting than just differentiating between men and women farmers**.

Women often face a general pattern of discrimination that affects their access to many, if not all, the key ingredients needed for technology adoption, including land, technology, knowledge, inputs, credit and markets. Finding ways to empower women that overcome this overall pattern of discrimination would level the playing field and be far more effective than addressing each constraint on its own. However, as Peterman et al (2010) observe, this is not just a legal, political or economic issue: it requires changing gender relations, views and social institutions in many settings. Agricultural projects and programmes can contribute to this end by recognising the range of barriers that women and girls face in accessing programme benefits, taking action where possible, and avoiding the risk of entrenching discrimination and exclusion.

Box 4 Some innovative approaches to addressing adoption constraints for small farms (Hazell, 2010)

Improving access to knowledge. Participatory research methods and farmer field schools have been developed as ways of (1) engaging small farmers more directly in the design and testing of new technologies to better meet their needs, and (2) providing information and training on an interactive basis. Such approaches seem especially promising for meeting the needs of many women and poor farmers (Davis et al, 2010; Quisumbing & Pandolfelli, 2010). However, questions remain about their costs and whether their impacts can be scaled up beyond the relatively small numbers of farmers directly involved. New developments in decentralising the management of public extension systems and engaging with new partners from the private and NGO sectors also look promising, but there is still a weak evidence base about their effectiveness, especially in reaching women and poor farmers.

Improving access to markets and inputs. There have been a lot of interesting developments in ways of linking small farms to high-value chains, either through contract-farming arrangements with agribusiness partners or through membership of a producer group or other intermediary organisation. Wiggins and Keats (2013) provide a useful review of approaches with many illustrative case studies. These kinds of linkages show promise for enabling more women and poor farmers to sell into high-value markets, although evidence on this is still inadequate. So far, the number of small farms benefiting from these types of linkages remains relatively small, and more work is needed on ways of scaling up from successes.

Smart subsidies. There is much interest today in the design of 'smart' subsidies that can help kick start fertiliser use and private distribution systems, and speed up adoption of complementary technologies like improved seeds. To keep the costs of a fertiliser subsidy down, the subsidy rate should be targeted to avoid displacing existing commercial sales, and have a definite sunset clause. At this stage, vouchers look most promising as an effective delivery mechanism for a smart subsidy, and if they are redeemed through private agro-dealers they can also help build up a fully privatised procurement and distribution system (Minot & Benson 2009). They may also be relatively easy to target and phase out. However, they do have some problems and their use still needs rigorous evaluation in a variety of settings. Malawi has pioneered the use of smart subsides in the form of seed and fertiliser packs, and the experience has recently been evaluated by Chirwa and Dorward (2013), as summarised in
Box 5.

Rural finance. The reform of rural financial markets has led to a situation where many small farms are too big to rely on microfinance for their farm credit needs, and too small to be served by commercial lenders. A number of promising approaches have emerged to fill this gap.

One is value chain financing (VCF), made possible by new opportunities for interlinking markets for inputs, outputs and credit in today's more integrated value chains. In practice, VCF can be as simple as a trader providing a cash advance and accepting payment in kind at harvest time. Alternatively, it can be a more sophisticated configuration in which banks or external financiers provide credit to agribusinesses and traders who, in turn, lend to farmer associations or individual farmers under various types of contract arrangements (Swinnen & Maertens 2010). Credit guarantees that underwrite part of the risk along value chains are also a promising way of leveraging more commercial bank lending to small farmers and small- and medium-sized agribusinesses. For example, AGRA, under its Innovative Finance programme, has provided credit guarantees to the Standard Bank that have leveraged US$100 million in loans to smallholder farmers and small agricultural businesses – US$25 million each in Tanzania, Mozambique, Ghana and Uganda. Another promising approach is lending against warehouse receipts, which enable farmers to borrow against their harvest once graded and stored in a public or privately commissioned warehouse.

Risk management. Many governments have turned away from direct public interventions like crop insurance and price stabilisation, and are looking to market mediated approaches such as weather index insurance and futures markets to help small farmers manage risk. Weather index insurance shows promise, but common problems have arisen in pilot programmes, such as low farmer demand due to high basis risk and perceived low benefits, and the difficulty and cost of setting up an effective delivery network.

A recent review of some 40 pilot programmes concluded that these problems are more easily overcome if the insurance is linked to credit and a technology package that offers the farmer a real value-adding proposition that goes beyond simple risk management (International Fund for Agricultural Development and World Food Programme, 2010). Apart from a few export crops, relevant futures markets do not exist for most developing country farmers. Most small farmers need intermediaries to access the futures markets that do exist on their behalf (Hazell, 2011; Larson et al, 2004). The few opportunities that arise involve traditional export crops. Given the limited reach of index insurance and futures markets, most small farmers must rely on themselves and their communities to manage risk, and on public relief programmes when catastrophic losses arise.

Land rights.[2] Many small farms and women farmers do not have secure access to their land; this is an impediment to investing in some types of technology, especially those with long gestation periods. Formal land titling seems to be a more effective approach in Asia than Africa, partly because land rights are already secure at the community level within many of Africa's customary land tenure systems (Deininger, 2014; Feder & Nishio, 1999). While there are circumstances where land titling is justified in sub-Saharan Africa, more cost effective and politically feasible alternatives often exist. Improvements to land rental and sales markets can be helpful, such as reforming rental laws and streamlining procedures for registering and enforcing contracts and resolving disputes.

Where customary land rights still prevail, it may be better to strengthen and build on existing systems rather than replace them. In fact, land titling might undermine customary systems, creating conflicting rights that adversely affect the rights of women and secondary land users (Bruce & Migot-Adholla, 1994; Deininger & Feder, 2009). One approach is to reinforce local institutions by titling land at the community level. A number of African governments have initiated land policy and legislative reforms based on these principles: Mozambique, Namibia, Niger, Tanzania, Uganda, and South Africa (Deininger, 2014).

One of the most difficult challenges is securing land rights for women. For example, in much of sub-Saharan Africa, there is no concept of co-ownership of property by husband and wife under customary law, so formalising customary arrangements without first changing women's inheritance and ownership rights can lead to catastrophic outcomes for women (Joireman, 2007). Although many African countries now give attention to gender equality in national legislation, implementation remains constrained by deeply rooted cultural norms, compounded by women's lack of access to legal institutions, especially in rural areas. Creating law regarding co-ownership without effective enforcement of that law will not improve the current situation (ibid; Meinzen-Dick & Mwangi 2008). Additionally, the education of legal and traditional authorities and men and women is needed in areas where customary law might conflict with new statutes.

In all areas of land policy there is growing evidence to show that transparent and easy access to land records, such as is now possible through digitisation and the internet, can facilitate more secure rights for small farmers, improve the efficiency of land markets, and enhance the value of land for collateral purposes.

2 See also the Topic Guide on Land published by Evidence on Demand in March 2014: http://dx.doi.org/10.12774/eod_tg.mar2014.lockehenley

Box 5 The experience with targeted fertiliser subsidies in Malawi (Chirwa & Dorward, 2013)

Malawi introduced a starter pack scheme in 1998/99 to provide smallholders with modest amounts of fertiliser and improved seeds for growing maize. This was initially intended as a way of promoting fertiliser and seed uptake, but was then downscaled to focus on improving the food security of vulnerable households. Recurrent food security problems led to a much-expanded subsidy programme beginning in 2005/06 to achieve the broader goals of improving national food production and self-sufficiency. By 2008/09, around 1.5 million farmers (about 60% of the total) were each receiving one or two vouchers for 50kg bags of fertiliser.

Chirwa and Dorward (2013) estimate that the programme led to sizeable increases in the use of fertiliser and in national maize production. Despite these measures costing between 7% and 9% of the government's total budget each year (and 16% in 2008/09 when fertiliser prices rocketed), benefit/cost ratios averaged over 1.2 during 2005/06 to 2010/11, and over 1.3 if secondary rounds of growth induced by production and income increases are factored in (ibid).

The impact on the poor is more nuanced. Based on beneficiary interviews and livelihood modelling: "impacts (of vouchers) on beneficiary households show immediate benefits in maize production, net crop income, household income, and to a lesser extent food consumption, with continued (lagged) benefits on beneficiaries' maize production, and to a lesser extent food consumption. School enrolment and child health also appear to have benefited from subsidy receipt. No significant impacts of subsidy receipt were detected on subjective wellbeing and investment in physical assets, but this may be affected by investment of gains from increased maize production in food consumption, school enrolment, and health" (ibid). Chirwa and Dorward also found that fertiliser use on female-controlled plots increased with receipt of the vouchers.

SECTION 5

Productivity growth and poverty

Low agricultural productivity is a primary cause of poverty for many rural households, so agricultural productivity growth ought to be a powerful way of reducing poverty. However, the links between agricultural productivity growth and poverty outcomes are complex and have been the subject of considerable controversy in the literature.

Impact pathways

There are a number of pathways through which improved technologies could potentially benefit the poor (Hazell & Haddad, 2001). Within adopting regions, poor farmers could gain directly through increased own-farm production, providing more food and nutrients for their own consumption and increasing the output they can sell for cash income. Small farm and landless labourer households could gain additional employment opportunities and higher wages within adopting regions, both in agriculture and the local non-farm economy. Productivity growth could also empower the poor by increasing their access to decision-making processes, enhancing their capacity for collective action, and reducing their vulnerability to economic shocks via asset accumulation.

Poor people outside adopting regions might also gain indirectly from new technologies. Growth in adopting regions could create employment opportunities for migrant workers from other less dynamic regions. It could also stimulate growth in the rural and urban non-farm economy with benefits for a wide range of rural and urban poor people. By reducing production costs per unit of output (e.g. per kilogram of rice), productivity growth could lead to lower food prices (and hence greater purchasing power) which could provide an immense benefit for poor people.

However, technology uptake could also work against the poor. Some technologies are more suited to larger farms, or require inputs that may only be affordable for or accessible to large farms. Some technologies (e.g. mechanisation and herbicides) could displace labour, leading to lower earnings for agricultural workers. By increasing the returns to land, technology may lead to higher land rents and reduced access to rental land for the poor. Rising farm incomes might also lead to changes in consumption patterns that favour industrial and imported goods at the expense of locally produced artisan products that are produced by the poor (e.g. plastic shoes from China can displace the local cobbler). By favouring some regions over others, technology could harm poor farmers in non-adopting regions by lowering their product prices, but without the offsetting cost reductions associated with the technology.

Given that many of the rural poor are simultaneously farmers, paid agricultural workers, net buyers of food, and earners of income from non-farm sources, the impacts of technological change on their poverty status can be difficult to assess, with households experiencing gains in some dimensions and losses in others. For example, a poor farm household might gain from increased own-farm production and higher wage earnings, but lose from lower farm gate prices and higher land rents. Measuring net benefits to the poor requires a full household livelihood analysis of all direct and indirect impacts, as well as consideration of the impacts on poor households that are not engaged in agriculture and/or who live outside adopting regions, including the urban poor.

Much of the controversy that exists in the literature about how new technologies and productivity growth have an impact on the poor has arisen because too many studies have only taken a partial view of the problem. For example, many studies have only assessed the direct and often short-term impacts on adopting farm households. There has also been confusion over the scale at which poverty impacts are measured. Since there can be winners and losers both at the household and regional level and between rural and urban people, then results can be very different depending on whether poverty reduction is measured within adopting regions or for a country as a whole, and whether it is assessed separately for rural and urban people.

Micro-level evidence from within regions of adoption

The initial experience with the Green Revolution in Asia and in Latin America and the Caribbean (LAC) stimulated a huge number of studies on how technological change affects small farmers and landless workers within adopting regions. A number of village and household studies conducted soon after the release of Green Revolution technologies raised concerns that large farms were the main beneficiaries of the technologies and that small farmers were either unaffected or made worse off – Griffin (1972) and Frankel (1976) were influential critics at the time. Later evidence showed that, while small farmers did lag behind large farmers in adopting the new technologies, many of them eventually did catch up within a few years. In a comprehensive review of the literature some 10 years later, Lipton (1989) found that many small-farm adopters benefited from increased production, greater employment opportunities, and higher wages in the agricultural and non-farm sectors.

Much of the literature in the 1970s and 1980s was focused on changes in inequality and income distribution rather than absolute poverty, the latter emerging as a more important goal in the 1990s with the crystallisation of the Millennium Development Goals (MDGs) (in fact, hardly any countries even reported poverty data before the 1990s). In an early example of meta-analysis, Freebairn (1995) reviewed 307 published studies on the Green Revolution to evaluate impacts on income inequality. He found that 40% of the studies reported that income became more concentrated within adopting regions, 12% reported that it remained unchanged or improved, and 48% offered no conclusion. He also found there were more favourable outcomes in the literature on Asia than elsewhere, and that within the Asian studies, Asian authors gave more favourable conclusions than non-Asian authors. Whether this reflected differences in the ideological biases of researchers in approaching data sets, or the choice of case studies, is not known.

Other lessons drawn from this rich literature include a better understanding of the conditions under which agricultural research is on balance pro-poor within adopting regions. These conditions can be quite specific to the local socio-economic context, especially the distribution of land, small farmers' access to knowledge, key inputs and markets, and the empowerment of women farmers. National policies also matter, as can be inferred from the earlier discussion on public interventions for overcoming constraints to technology adoption, especially by poor and women farmers.

Indirect impacts and aggregate impacts

Complementing these many micro studies, a number of analysts have used cross-country and/or time-series data to estimate more aggregate relationships between agricultural growth and poverty reduction. These relationships capture many of the indirect as well as the direct impacts of agricultural productivity growth on the poor. As discussed in Section 4, aggregate studies of returns to agricultural R&D must contend with a number of potential statistical problems, and the ability to make appropriate adjustments to avoid misleading results is constrained by the scope and quality of the available data set.

Results are typically reported in the form of growth-poverty elasticities, which measure the percentage change in poverty associated with each 1% increase in agricultural output or productivity. In a widely cited study, Thirtle et al (2003) estimate that a 1% increase in crop productivity reduces the number of poor people by 0.72% in Africa and by 0.48% in Asia. For India, Ravallion and Datt (1996) estimate the elasticity of poverty reduction with respect to agricultural value added per hectare at 0.4% in the short run and 1.9% in the long run, the latter arising through the indirect effects of lower food prices and higher wages. Studies that compare growth-poverty elasticities across sectors typically find much higher elasticities for agriculture than for non-agriculture (Christiaensen & Demery 2007; World Bank 2007).

Some studies have also quantified more explicitly the links between public investments in agricultural R&D, agricultural productivity growth and poverty reduction, and provided comparisons with other types of public rural investments. An IFPRI study by Fan et al (1999) estimates that in India, during 1970-93, public investments in agricultural R&D had the second highest impact on rural poverty after roads (see Table 3). They also found that agricultural R&D generated more agricultural TFP per rupee spent than any of the other public investments considered, so that agricultural R&D is an attractive win-win option for agricultural growth and poverty reduction. Studies of China, Thailand and Uganda also show high rankings for agricultural R&D in promoting poverty reduction and agricultural growth (Fan & Rao 2008).

Type of public rural investment	Poverty elasticities (% change in poverty for 1% increase in public spending, by item)	Number of poor reduced per million rupees spent, by item
Agricultural R&D	-0.065*%	91.4*
Irrigation	-0.007	7.4
Roads	-0.066*	165.0*
Education	-0.054*	31.7*
Power	-0.002	2.9
Soil and water conservation	-0.0004	6.7*
Health	-0.0007	4.0
Rural development (antipoverty programmes)	-0.019*	27.8*

** Significant at the 5 percent level*

Table 3 Poverty impacts of agricultural research in India, state-level analysis, 1970-93 (Fan et al, 1999)

In a rare attempt to single out the impact of agricultural R&D on the urban poor, Fan (2007) estimates that, in India, during 1970-1995, the cumulative impact of agricultural research investments through TFP growth lifted between 2% and 2.5% of the remaining urban poor out of poverty each year. This was primarily through reductions in food prices. Since the same investment in research also lifted many rural poor out of poverty, there was a double dividend that made agricultural research investments especially attractive.

Another body of literature analyses the indirect income and employment created in the non-farm economy (NFE) as a consequence of agricultural productivity growth, and how these might have benefited the poor. Some studies limit their analysis to growth linkage benefits within the NFE of adopting regions, while others attempt to capture the NFE benefits at the national level. Analytical approaches vary from simple linear, fixed price input-output and semi-input-output multiplier models, to econometric modelling and estimation, to simulations with computable general equilibrium (CGE) models.

Haggblade et al (2007) compare multiplier estimates (in Table 7.3) from a variety of empirical studies using different methods. They report multipliers that measure the total income created in a regional or national economy for an additional £1 originating in agriculture – a multiplier of 1.5 therefore means that another £1 income generated in agriculture leads to a £0.5 gain in NFE income, and a total income gain of £1.5 to the economy. Most estimates of regional multipliers fall in the 1.3-2.0 range, while national multipliers fall in the 1.5-3.0 range. The multipliers are typically lower when estimated with price endogenous or econometric models than with different variants of input-output models. They are also typically higher for Asia than for Africa and Latin America, one reason being that Asia's more input-intensive farming systems have stronger linkages to NFE.

Another important result from this body of literature is that much of the indirect income growth induced in the rural NFE arises within the services and informal manufacturing sectors, and these are typically labour-intensive activities that are important to women and poor people. Consequently, the multipliers can lead to substantial benefits for the poor (Haggblade et al, 2007; Hazell & Haggblade, 1993).

Future challenges

In summary, agricultural productivity growth has had mixed direct impacts on the poor within adopting regions, with outcomes being sensitive to local socio-economic conditions and national policies. On the other hand, indirect impacts on the wider population of rural and urban poor through lower food prices, higher wages, and growth linkages to NFE seem to have been powerful and more consistently positive. They are often powerful enough to more than offset any negative direct impacts within adopting regions (as evidenced by the sizeable poverty elasticity estimates reported above).

Experience also suggests that policies matter, and it may be asking too much to expect that agricultural R&D on its own can make all the poor better off; complementary policies to help spread the benefits may be needed. Box 3, for example, describes how India pursued a set of policies that helped ensure small farms were not left out of the Green Revolution, and which contributed to more favourable outcomes for the poor within adopting regions than would otherwise have been the case.

Some of the lessons from this vast literature on productivity growth and poverty may have to be qualified today because circumstances have changed since the Green Revolution era. Prominent among these changes are that globalisation and market liberalisation policies and rapid urbanisation have transformed the economic context for agricultural growth in most countries, and made food prices less contingent on national production. Small farms have also become smaller (in India, for example, they are now less than half the size of small farms during the Green Revolution), and small farm households are much more diversified into off-farm sources of income (Masters et al, 2013). Also, the majority of the rural poor now live in less-favoured regions that missed out on the Green Revolution, and where the potential to raise agricultural productivity can be more challenging (Ghani, 2010; Hazell & Wood, 2008; World Bank, 2007). Within this changed context, many poor rural households with limited access to land might gain more from migration and non-farm opportunities than from productivity gains or wage earnings in farming, and the urban poor might benefit more from agricultural trade policies than from increases in national food production (Dercon & Collier, 2013).

These changes do not rule out an important future role for agricultural productivity growth to benefit the poor, but they do suggest that investments like agricultural R&D may need to be targeted differently than in the past. For example, a recent foresight study sponsored by the

Independent Science and Partnership Council (ISPC) of CGIAR concludes that agricultural R&D investments for small farms need to be differentiated according to the regional context in which farmers live and the market orientation of the farmers (Masters et al, 2013).

In particular, Masters et al (ibid) distinguish between favoured areas that have good agricultural production potential and/or good market access, and less-favoured regions with poor agricultural production potential and/or poor market access. Favoured regions provide many more business opportunities for small farms, particularly in today's world of rapid urbanisation and globalisation of agricultural value chains. The opportunities for shifting into higher-value agriculture for urban and export markets can be particularly attractive as, for example, in some of the rural hinterlands around large cities in India, China, and Mexico. This is also true of the opportunities for producing fresh horticultural products for export in Kenya and Central America. In less-favoured regions, market opportunities for most small farms are much more constrained, and crop yields can be expected to be lower. These regions tend to be much less competitive, more risky, and orientated to production of staple foods, largely for local consumption.

Within these two types of regions, it is also recommended that a distinction is made between market-orientated farmers who are more likely to succeed on a commercial basis, and transition or subsistence-orientated farmers who are either at various stages of transition out of farming or who farm primarily to meet own subsistence needs. The kinds of technologies and assistance appropriate for these two groups can be quite different, with implications for the kinds of R&D they need and whether the private or public sector is best positioned to provide it.

Further research is needed to develop and test the relevance of smallholder typologies for targeted R&D and other forms of small farm assistance, including developing practical ways of identifying the different groups of farms on the ground. There has been a lot of recent work using GIS and spatial analysis methods to identify target areas for rural development purposes. Most of this work focuses on mapping different regions in terms of their agro-ecology, market access, and rural population density (see, for example, Omamo et al, 2006); however, there has been limited work so far on disaggregating further, according to differences in farmer endowments, market orientation, and gender.

SECTION 6

Productivity growth and sustainability

There are serious concerns today that many of the more successful pathways to agricultural productivity growth are not sustainable from an environmental perspective. Given the growing human demands on farming systems, attempts to achieve environmentally sustainable solutions at current or lower levels of productivity will not be enough, and the real need is for further productivity growth but on a sustainable basis. This is often referred to as ‘sustainable intensification’.

There are serious questions about the long-term sustainability of many past patterns of agricultural productivity growth. In intensive (often irrigated) farming systems there are continuing problems with surface water and aquifer depletion, water logging and salt build-up in irrigated lands, pesticide poisoning, chemical (especially nitrate) pollution of waterways, biodiversity loss, and greenhouse gas emissions. In extensive farming systems, often located in low-potential and unirrigated areas, the main problems are expansion of the agricultural area into remaining forest, habitat and biodiversity loss, soil erosion, soil fertility depletion, degradation of watersheds, and decreasing carbon sequestration capacity (Hazell & Wood, 2008). The resilience of many farming systems is also being challenged by climate change.

A priority for irrigated farming must be to improve water-use efficiency while substantially reducing total water use, water pollution, land degradation, and the unsustainable mining of groundwater. Many suitable technologies and natural resource management (NRM) practices have been developed. These include improved fertiliser management (involving better choices about fertiliser types and application rates and timings to better match the changing nutrient needs of plants over their growing season). Other examples are the system of rice intensification or SRI (see Box 6), greater use of ecological principles in pest management – as in integrated pest management (IPM) (see Box 7) – and improved water management practices (World Bank, 2007).

A priority in many extensive farming systems is to increase land and labour productivity through more intensive farming approaches that can reduce human pressure on the natural resource base. One promising technology that has already had far-ranging impacts in many hillside and agro-pastoral areas is agroforestry (Place et al, 2002). Another technology, conservation farming, has been successfully adapted to a wide range of conditions in Latin America, Asia and Africa (see Box 8). In the Sahelian countries, simple and low-cost bunding techniques and tree planting retain soil nutrients and reduce erosion, leading to higher and more stable yields and incomes (Haggblade et al, 2010; Reij et al, 2009). Small-scale watershed development projects have been shown to increase farm incomes and reduce soil erosion in some of the lower rainfall areas of Ethiopia and India (Pender et al, 2006; Kerr et al, 2002; Joshi et al, 2005). Small-scale, farmer-controlled irrigation developments that use simple and low-cost technologies like river diversion, lifting with small (hand or rope) pumps from shallow groundwater or rivers, or seasonal flooding, enjoy localised successes in Africa, especially when used to grow high-value horticulture crops (World Bank, 2007).

Box 6 System of rice intensification (SRI) (Hazell, 2008)

SRI was developed in the early 1980s by Henri de Laulanie, a French missionary priest in Madagascar, as an alternative approach to the standard Green Revolution rice technologies for small-scale farmers. It has since been widely promoted by a number of NGOs and the International Institute for Food, Agriculture and Development (IIFAD) at Cornell University.

The main components of SRI are as follows: transplanting of young seedlings (8-15-day-old instead of 3-4-week-old plants) on small hills at much lower plant densities than usual; water management that keeps the soil moist rather than flooded; frequent weeding; use of large amounts of organic compost for fertiliser.

The claimed benefits include high yields, even with traditional rice varieties; significant savings in seed; little or no artificial fertiliser required; natural pest and disease control, eliminating the need for pesticides; reduced water use; a flexible management system that allows farmers to experiment and adapt the approach to their particular growing conditions. The approach is claimed to be environmentally sustainable and of particular relevance for poorer farmers who cannot afford modern inputs (Uphoff, 2003).

SRI has generated enormous controversy, largely because of claims of very high yields, sometimes exceeding the best experiment station yields for modern rice technologies, sometimes even without the use of fertiliser or modern varieties. These high yields defy current understanding of the physiology of rice plant growth (Sheehy et al, 2005). Proponents argue that there are strong synergies between the different management components of SRI that lead to strong root growth and higher yields, although these synergies are not well understood (Mishra et al, 2006).

Few of the yield claims have been verified under controlled experimental conditions. Trials undertaken at IRRI found no significant yield differences between SRI and conventional GR practices (Namara et al, 2003). McDonald et al (2006) analysed 40 sets of field trial results reported in the literature (five from Madagascar and 35 from 11 Asian countries) which compared SRI with ‘best management practices’ appropriate to each site. Apart from the five Madagascar studies, which consistently showed higher yields with SRI, SRI led to an average yield loss of 11% in the other 35 studies, with a range of -61% to 22%.

Yield gains appear to be better in farm-adoption studies. Farmers in Ratnapura and Kurunegala Districts in Sri Lanka obtained 44% higher yields on average with SRI than with modern rice farming methods (Namara et al, 2003), and the average yield gain was 32% for farmers in Purila District of West Bengal (Sinha & Talati, 2007). However, in both studies SRI farmers showed considerable variation in the management methods they used, making it rather unclear as to what was being compared in the name of SRI. For example, many SRI farmers used inorganic fertiliser as well as compost, many grew modern as well as traditional rice varieties, and their weeding and water management practices varied considerably.

SRI has yet to be widely adopted in any one country, although it can be found on a small scale in many countries, including many parts of South Asia. Some of the reasons for poor uptake include the difficulties of controlling water with sufficient precision in many surface irrigation systems, the need for large amounts of compost, and the high labour demands for transplanting, hand weeding, and generating and distributing compost. This is confirmed by available adoption studies. In Sri Lanka, adoption is positively related to family size (availability of labour) and ownership of animals (availability of manure), and is more common among rainfed than irrigated rice farmers (Namara et al, 2003). Moser and Barrett (2003) obtained similar results in an adoption study in Madagascar. Moser and Barrett (ibid), Namara et al (2003) and Sinha and Talati (2007) all found that adopters only practice SRI on small parts of their rice area despite higher returns to both land and labour, and they also found high rates of disadoption. This again suggests important constraints, possibly labour or suitability of available irrigation systems, as well as disappointing returns.

Controversy about SRI continues, and the best conclusion may be that there are some features of the approach, such as improved planting densities and water-management practices, can be usefully incorporated into modern rice growing practices without giving up the advantages of using improved varieties and fertilisers.

Box 7 Integrated pest management (IPM)

Pest problems emerged as an important problem during the early Green Revolution era because many of the high-yielding varieties first released had poor resistance to some important insect pests and diseases. The problem was compounded by a shift to higher cropping intensities, monocropping, high fertiliser use (which creates dense, lush canopies in which pests can thrive), and the planting of large adjacent areas to similar varieties with a common susceptibility. Control was initially based on prophylactic chemical applications, driven by the calendar rather than incidence of pest attack. This approach disrupted the natural pest-predator balance, and led to a resurgence of pest populations that required even more pesticide applications to control. Problems were compounded by the build-up of pest resistance to the commonly used pesticides. As pesticide use increased so did environmental and health problems. One study (Rola & Pingali, 1993) found that the health costs of pesticide use in rice reached the point where they more than offset the economic benefits from pest control.

As problems with the use of pesticides began to emerge, researchers gave greater attention to the development of crop varieties that have good resistance to important pests, and biological and ecological pest-control methods. This led to the development of integrated pest management (IPM), an approach that integrates pest-resistant varieties, agronomic and biological means of control, and the judicious and selective use of pesticides only when pest attacks occur. IPM was promoted widely across Asia beginning in the 1980s, backed by policy changes that made pesticides more expensive (e.g. removing subsidies or imposing import tariffs), as in Indonesia, Bangladesh and The Philippines. Although IPM was initially developed for rice, IPM approaches have since been developed for many other crops.

Studies show that the main advantages of IPM for farmers arise from reduced labour and pesticide costs rather than higher yields, and from reduced health problems (e.g. Susmita et al, 2007). However, the scale of adoption has been disappointing. An important constraint is that IPM is a knowledge-based technology that needs to be adapted to specific locations and situations, and this poses serious challenges in regions with large numbers of small farms. Farmer Field Schools (FFS) have proven an effective approach for promoting IPM, but are costly and only train a few farmers at a time. There is little evidence to show that knowledge spreads spontaneously from trained to untrained farmers.

Box 8 Conservation agriculture (World Bank, 2007; Hobbs et al, 2007)

Conservation agriculture (CA) is a system of crop farming that was developed in response to the Dust Bowl of the 1930s in the US Great Plains that resulted from excessive tillage. Conservation agriculture is based on three principles, designed to enhance biodiversity above and below ground: a) minimum or no mechanical soil disturbance throughout the entire crop rotation, b) permanent organic soil cover through cropping and mulching, and c) diversified crop rotations in the case of annual crops or plant associations in the case of perennial crops.

The claimed benefits of CA include reduced wind and water erosion, better weed control, conservation of soil moisture, and improved soil organic matter and fertility. CA also saves on mechanisation costs and greenhouse gas emissions, and sequesters more carbon in the soil. Weed control can be a problem, and it was only after the development of selective herbicides that the practice began to spread across North and South America and, to a lesser degree, in Europe. Farmers in Iowa (USA), for example, growing maize on their deep, highly organic long-grass prairie soil, do not till their land, but do apply herbicides to control the weeds. In 2004/05, worldwide adoption of CA was about 95 million hectares (or about 6.7% of the total cropped area).

CA principles are now being applied in many parts of Africa, by national agricultural research systems (NARS) and by NGOs. In these circumstances, weeding is still a challenge but is being tackled relatively successfully by hand weeding, without the use of herbicides. In general, yields under CA are significantly higher than under conventional farming in large part due to improved soil and water conservation.

While it is relatively easy to demonstrate the yield and income impacts of these kinds of technologies and NRM practices, assessing their longer-term environmental impacts is more challenging, and there are few impact studies that have succeeded (Renkow & Byerlee, 2010). This is partly because of difficulties in measuring environmental changes over the time spans and levels of scale (e.g. from plot to landscape to watershed) required, and also because of difficulties in assigning economic values to changes even when they can be measured (Freeman et al, 2005). The few impact studies that exist either report changes in selected physical indicators or rely on farmers' perceptions of change in resource or environmental condition (e.g. Kerr et al, 2002), or rely on model simulations.

Despite the development of and successful demonstration of many better technologies and NRM practices for reducing environmental problems in agriculture, their uptake and spread remains grossly inadequate. Like other technologies, most of the adoption constraints listed in

Box 2 apply, but some factors are especially important (Shiferaw et al, 2009). One is the high knowledge and labour requirements of many improved NRM practices (Tripp, 2006). Another is the need for collective action for NRM practices that need to be implemented at the landscape level (e.g. soil erosion control and watershed development) or by groups of adjacent farmers (e.g. IPM and improved water management practices) (Meinzen-Dick et al, 2002). In some cases, subsidies on water, fertilisers and pesticides act to encourage farmers to use excessive amounts of these inputs, thereby working against responsible environmental management.

Another widespread problem is the offsite (or externality) nature of many environmental problems, meaning that the farmers who cause an environmental problem do not bear the full consequences of the damage. With water pollution, for example, it is the people who live downstream of the offending farmers who suffer the consequences. Again, farmers who mine groundwater have an impact on all users in a watershed. In these kinds of cases, the standard policy approach is to regulate and penalise the farmers causing the problem, but this requires more effective public institutions and enforcement systems than exist in most developing countries. Sometimes solutions can be found in local organisations that bring key stakeholders together (e.g. river basin management authorities provide a forum for linking upstream and downstream users).

Not all externalities are costs. Some externalities lead to benefits, such as the provision of important environmental services like watershed and habitat protection, and carbon sequestration. These can be of considerable benefit to societies at large, but the farmers and communities who provide these services are not rewarded for their efforts in the market. The result is that they engage in farming practices which, even if sustainable, do not provide sufficient environmental services. In these cases there may be need for some form of financial compensation (World Bank, 2007).

British and European farmers are compensated for providing environmental services on their farms, such as protecting headlands, hedges and wildlife. Unfortunately, few developing countries can afford these kinds of payments and more promising solutions lie in the emergence of market based schemes for paying for environmental services (PES). Emerging carbon payment markets are a good example, and under some circumstances can be used to pay farmers for sequestering carbon in their landscapes. The payment originates from private industries that must stay within carbon caps either by reducing their own emissions or by paying others to make compensating carbon offsets. So far there is limited experience in using PES in agriculture, but a lot of interesting pilot schemes are being tried (World Bank, 2007).[3]

[3] A Topic Guide on Ecosystems Services will be published by Evidence on Demand in June 2014.

SECTION 7

Productivity growth in conflict areas

Most conflicts in the developing world take place in rural areas, displacing large numbers of civilians, disrupting their agricultural livelihoods, and undermining agricultural productivity and food supplies. Rebuilding agriculture is an important strategy for post-conflict reconstruction. It not only offers an opportunity to improve food security and enhance livelihoods, but agriculture is also well suited to absorb demobilised combatants.

An immediate need for restoring agricultural production in post-conflict situations is to provide agricultural inputs and assets including seeds, tools, and livestock that have been lost during the conflict. Most post-conflict programmes give high priority to providing these inputs, but as Birner et al (2011) note: “Programmes that distribute such inputs are subject to substantial governance challenges, such as leakage of funds and procurement of sub-standard material. Moreover, unlike community infrastructure such as schools or boreholes, agricultural inputs are private goods, and the challenge of capture by better-off households is particularly pronounced. In post-conflict situations, additional challenges arise due to the limited capacity of both government and community-based institutions to implement such programs effectively”. Capture and sub-standard materials are not just a problem of leakages, but can breed resentment that leads to renewed conflict.

In providing key agricultural inputs, development agencies and governments have tried a variety of approaches to overcoming governance problems, including the decentralisation of programme implementation to local governments, the use of community-based procurement approaches, and the use of vouchers for agricultural inputs. There is limited evaluation evidence on how well these various approaches work, and hardly any literature that compares their performance in resolving governance challenges. An exception is Birner et al (2011), who studied the agricultural input supply programmes implemented in post-conflict northern Uganda. Their study evaluates and compares the performance of two World Bank-funded government programmes: the National Agricultural Advisory Services programme (NAADS) and the Northern Uganda Social Action Fund (NUSAF); two programmes funded by DANIDA; a Caritas programme; a programme of the International Committee of the Red Cross; a programme run by the NGO Heifer International. Together, these programmes provided contrasting experiences in the same region on four different implementation mechanisms: (1) public procurement of inputs either by government agencies or by NGO implementing agencies; (2) procurement of inputs by community groups, with funds being channelled either through local government accounts or the groups’ own accounts; (3) input voucher programmes with a public works component, or without a public works component; (4) cash-for-work programmes with incentives for investment in agriculture.

Using a modified policy network analysis framework and stakeholder interviews, Birner et al find that each approach has strengths and weaknesses in overcoming governance problems. For example, combating corruption among public officials using community-based procurement may come at the expense of elite capture in community groups. Additionally, using specialised organisations for delivering post-conflict programmes may work well in the short run, but may affect the possibility of creating well-functioning institutions in the long run. Moreover, many interesting approaches work well on a small scale when implemented by dedicated and committed project teams; however, scaling up such experiences is not easy. Nevertheless, scaling up is necessary if agriculture is to be rebuilt and peace assured at the regional level.

The performance of rural producer organisations (RPOs) in bridging the gap in service provision in post-conflict situations is also analysed by Ragasa and Golan (2012). They surveyed a sample of RPOs in the Democratic Republic of the Congo (DRC) and found that success in terms of performing well and benefiting their members depended on an enabling environment, good governance, and security, all of which can be difficult to achieve in post-conflict situations, especially if they depend on a broader range of governance and institutional reforms that extend well beyond the agricultural sector (World Bank, 2011).

It is often argued that agriculture can make important contributions to avoiding conflicts. For example, poverty, inequality and weather shocks are all positively associated with conflict (ibid); therefore, investments in agricultural productivity growth that lead to inclusive and resilient patterns of rural growth should be helpful. This might be especially important in lagging regions that are heavily populated and in regions with large ethnic minorities. Although the logic seems impeccable, the empirical base to substantiate such claims remains mixed (de Soysa & Petter Gleditsch, 1999).

SECTION 8

Summary and future priorities

Summary

Since the 1960s, growth in global agricultural production has kept ahead of population growth, contributing to a downward trend in world food prices when adjusted for inflation, and a supply of food that is adequate to feed the entire world population to minimum UN standards were if more equitably distributed. The increased use of inputs, particularly water, fertilisers, and labour, explained about half the total increase in agricultural production between 1960 and 2007, while the remaining half was due to increases in agricultural productivity (i.e. to gains in the efficiency with which inputs are used in farming). Strikingly, this increase in productivity since 1960 has enabled agricultural production to grow without having to convert much additional land to farming, thus helping to retain large areas of land in forest and other environmentally valued uses. This favourable global perspective masks some important regional variation. While most parts of the developing world have successfully and continuously increased their agricultural output per capita since the 1960s, sub-Saharan Africa has experienced stagnant, even declining per capita output, and some regions have experienced more significant land conversion to agriculture.

Agricultural research has played a key role in raising agricultural productivity, both by contributing new and improved technologies that give more output per unit of input, and by helping farmers improve the efficiency of their management practices. The productivity returns to agricultural research have generally been high, although controversy remains about just how high in terms of the economic returns to the investments made.

Many farmers have benefited from increased productivity, but only when they have been able to adopt the improved technologies and management practices that became available. Adoption typically requires access to knowledge, key inputs and credit, and access to these inputs depends on local availability and household characteristics. For example, younger and more educated farmers tend more often to adopt, as do farms that are located near roads or market centres that facilitate access to agro-dealers and markets. Women farmers and poor farmers typically face the most constraints in adopting better technologies, and are most in need of supporting public policies. Recent years have seen a paradigm shift in policies for assisting farmers adopt new technologies, from a top-down public sector supply model to one in which the public sector works through a myriad of private sector and NGO players. It is still too soon to know if this new paradigm will be sufficient to successfully reach many small farms, or poor and women farmers.

Agricultural productivity growth has been widely beneficial to the poor, especially where it has helped keep food prices lower than they would otherwise have been, and where it has generated additional income and employment opportunities in the farm and non-farm economy. However, the distribution of benefits within farming communities that have adopted new technologies has led to mixed outcomes for the poor, and which are conditioned by initial socio-economic conditions such as farm size distribution and prevailing agricultural policies.

Although agricultural productivity growth has saved large areas of forest and other valued land uses, it has also had negative impacts on the environment. Serious questions have arisen about the sustainability of some of the more intensively farmed areas. Agricultural research has contributed to the development of more sustainable and environmentally benign farming practices for intensive farming systems, but their widespread adoption remains disappointing. Some important reasons are their knowledge and labour intensity, and the distorted incentives that arise when governments subsidise the use of fertilisers and irrigation water, or where environmental costs arise off farm (i.e. they impact on people other than the ones causing the problem). It also needs to be recognised that many of the environmental problems associated with agriculture have little to do with intensive farming, but arise in areas that still depend on extensive farming practices and where population growth is placing high stresses on the natural resource base. In these cases, productivity growth through agricultural intensification needs to be part of the solution, along with more sustainable management practices.

Too slow agricultural productivity growth has been linked to violence and conflicts in rural areas, although the empirical evidence on this linkage is still less than compelling. What is clearer is that restoring agricultural productivity growth needs to be part of any strategy for post-conflict recovery.

Future Priorities

Looking to the future, most countries have limited opportunities for further expanding their agricultural area and irrigation capacity. Consequently, future agricultural growth will become more dependent on productivity growth rather than greater use of inputs and, as shown in **Table 1**, this is already reflected at the global level. There is no evidence to show that the returns to agricultural R&D are declining over time, but if they are to be maintained, the best hope lies then in further advances in biosciences and information technology. Farmers in many developed countries are already tapping into these sources of productivity growth, but their full impact has yet to be felt, especially in the developing world. Future research will also need to emphasise the need for sustainable intensification, and for adapting to climate change.

Agricultural productivity growth will also continue to be important for the poor. Poor people everywhere benefit from less costly food supplies; however, unlike the past, market liberalisation and globalisation have reduced the dependence of individual countries on their own food production and hence weakened the link between own production and prices. Yet, this relationship still holds globally, and persists in many land-locked regions and countries that do not have ready access to world supplies.

Small farms and women farmers have played dominant roles in past patterns of agricultural growth, and seem likely to continue to do so. Enhancing their on-farm productivity can still be important for enhancing their welfare and helping many escape poverty. However, agricultural research may need to be targeted differently in the future if it is to benefit these groups. Many small farms have become tiny and have diversified into off-farm sources of income, and now farm largely for their own consumption. Many of the poorest small farms are also located in less-favoured regions where agricultural productivity remains low and difficult to increase. At the same time, small farms wishing to expand into high value agriculture as a way of raising their productivity face hurdles in linking to modern value chains. In this changing context, the latest thinking is to differentiate farms on the basis of their regional context (e.g. favoured vs less-favoured regions in terms of agricultural potential and access to markets) and to distinguish between market-orientated vs subsistence-orientated farmers. Pro-poor research can then be targeted at subsistence-orientated farms and integrated alongside other complementary interventions that can assist them exit or diversify further out of farming; productivity-orientated research for more commercially-orientated farming can be targeted at market-orientated farmers along with interventions to help them link to modern market chains. In both cases, the regional context would help to define the opportunities available and, hence, the detailed interventions to pursue.

Recommended reading

Sections 2 and 3: Productivity growth – definitions and trends

For a good nontechnical review of recent trends in world food production, including the important role of productivity growth, see Chapter 2 in IFPRI's 2012 *Annual Food Policy Report*, available at: http://www.ifpri.org/sites/default/files/publications/gfpr2012_ch02.pdf

Section 4: What drives productivity growth?

Bob Evenson and Doug Gollin (2003) provide the most comprehensive analysis of the global evidence on the impact of crop-genetic improvement research over the period 1965-1998 for all the major food staple crops. They also break down CGIAR's contributions and find very large impacts, especially for rice, wheat and maize. Unfortunately this is an expensive hardcover book.

Mitch Renkow and Derek Byerlee (2010) review recent impact assessment studies of CGIAR research, including policy research, in terms of their contributions to productivity, poverty and environmental goals, available at:
http://impact.cgiar.org/pdf/RenkowByerlee2010.pdf

In *Slow Magic: Agricultural R&D a Century after Mendel,* Phil Pardey and Nienke Beintema (2001) provide an excellent review of trends in agricultural R&D spending around the world and the growing role of the private sector. They also review evidence on the impact of that spending, available at: http://www.ifpri.org/sites/default/files/publications/fpr31.pdf. For a 2012 update on R&D spending patterns, see:
http://www.ifpri.org/sites/default/files/publications/astiglobalassessment.pdf

On ways of overcoming constraints to adoption, a recent (2013) and comprehensive review is provided at *Feed the Future Learning Agenda Literature Review: Improved Agricultural Productivity*, USAID:
http://agrilinks.org/sites/default/files/resource/files/Feed%20the%20Future_Learning%20Agenda%20Literature%20Review_Ag%20Productivity_2013.pdf

On gender issues, Agnes Quisumbing and colleagues at IFPRI have written several comprehensive and evidence based reviews of the extent of discrimination against women in accessing key inputs for farming, and on approaches for overcoming the problem. Two key papers are:

> Peterman, A., Behrman, J. & Quisumbing, A. (2010) 'A review of empirical evidence on gender differences in nonland agricultural inputs, technology, and services in developing countries', *IFPRI Discussion Paper 975*. Available at: http://www.ifpri.org/sites/default/files/publications/ifpridp00975.pdf
>
> Quisumbing, A. & Pandolfelli, L. (2010) 'Promising approaches to address the needs of poor female farmers: Resources, constraints, and interventions', *World Development*, *38(4)*, p581-592. Available at: http://www.ifpri.org/sites/default/files/publications/ifpridp00882.pdf

Another study from the same team looks specifically at how gender issues should be incorporated into agricultural R&D: *Engendering Agricultural Research, Development, and Extension*: http://www.ifpri.org/sites/default/files/publications/rr176.pdf

On linking small farms to markets, Wiggins and Keats (2013) provide a very useful review of approaches with many illustrative case studies in *Leaping and Learning: Linking Smallholders to Markets*: https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/LeapingandLearning_FINAL.pdf

Section 5: Productivity growth and poverty

Peter Hazell and Lawrence Haddad (2001) provide a conceptual and empirical review of the evidence on the impact of agricultural research on the poor and how it might be better targeted in *Agricultural Research and Poverty Reduction*: http://www.ifpri.org/sites/default/files/publications/2020dp34.pdf

Luc Christiaensen and Lionel Demery (2007) review the evidence on the macro links between agricultural productivity growth and poverty, with a special emphasis on Africa in *Down to Earth: Agriculture and Poverty Reduction in Africa*: https://openknowledge.worldbank.org/bitstream/handle/10986/6624/387810AFR0Down101OFFICIAL0USE0ONLY1.pdf?sequence=1

Will Masters (2013) examines how agricultural R&D needs to be prioritised to address the problems of small farms within the context of increasing urbanisation and declining farm sizes in *Urbanization and Farm Size in Asia and Africa: Implications for Food Security and Agricultural Research*: http://www.sciencecouncil.cgiar.org/sections/strategy-trends

Section 6: Productivity growth and sustainability

A good review of the environmental problems associated with agriculture and promising ways of addressing them is provided in Chapter 8 (*Making agricultural systems more environmentally sustainable*) of the *World Development Report 2008: Agriculture for Development*: https://openknowledge.worldbank.org/bitstream/handle/10986/5990/WDR%202008%20-%20English.pdf?sequence=3

The Montpellier Panel Report 2013, *Sustainable Intensification: A New Paradigm for African Agriculture*, explores the general problem of defining and attaining sustainable intensification in Africa: http://www3.imperial.ac.uk/africanagriculturaldevelopment/themontpellierpanel/themontpellierpanelreport2013

Section 7: Productivity growth and conflict areas

There is hardly any evidence-based research on the best ways to restore agricultural productivity in conflict areas. An exception is a study by Regina Birner, Marc Cohen and John Ilukor, who studied and compared the performance of several different types of agricultural input supply programmes implemented in post-conflict northern Uganda in *Rebuilding Agricultural Livelihoods in Post-Conflict Situations: What are the Governance Challenges? The Case of Northern Uganda*: http://www.ifpri.org/sites/default/files/publications/usspwp07.pdf

References

Acemoglu, D. (2002) ‘Directed technical change’, *Review of Economic Studies 69*, p781-810.

Adato, M. & Meinzen-Dick, R. (eds.) (2007) *Agricultural Research, Livelihoods and Poverty: Studies of Economic and Social Impacts in Six Countries*. Baltimore: Johns Hopkins University Press.

Alston, J., Chan-Kang, C., Marra, M., Pardey, P., & Wyatt, T. (2000) *A meta-analysis of rates of return to agricultural R&D,* ex pede herculem*? Research Report 113*. Washington, D.C.: IFPRI.

Alston, J., Norton, G. & Pardey, P. (1998) *Science under Scarcity: Principles and Practices for Agricultural Research Evaluation and Priority Setting*. Ithaca, N.Y.: Cornell University Press.

ASTI. (2012) *ASTI Global Assessment of Agricultural R&D Spending – Developing Countries Accelerate Investment*. Rome. Available at: http://www.asti.cgiar.org/pdf/ASTI_global_assessment.pdf

Binswanger-Mkhizi, H., de Regt, J. & Spector, S. (eds.) (2010) *Local and Community Driven Development: Moving to Scale in Theory and Practice.* Washington, D.C.: World Bank.

Birner, R., Cohen, M. & Ilukor, J. (2011) *Rebuilding Agricultural Livelihoods in Post-Conflict Situations: What are the Governance Challenges? The Case of Northern Uganda. Uganda Strategy Support Program (USSP) Working Paper No. USSP 07*. IFPRI. Available at: http://www.ifpri.org/sites/default/files/publications/usspwp07.pdf

Boserup, E. (1965) *The Conditions of Agricultural Growth*. New York: Aldine Publishing Company.

Bruce, J. & Migot-Adholla, S. (eds). (1994) *Searching for Land Tenure Security in Africa.* Dubuque, Iowa: Kendall/Hunt Publishing Co.

Chirwa, E. & Dorward, A. (2013) *Agricultural Input Subsidies and Malawi’s Recent Experience 2005-2010.* Oxford, UK: Oxford University Press.

Christiaensen, L. & Demery, L. (20070 *Down to Earth: Agriculture and Poverty Reduction in Africa.* Washington, D.C.: World Bank.

Davis, K., Nkonya, E., Kato, E., Mekonnen, D., Odendo, M., Miiro, R. & Nkuba, J. (2010) *Impact of Farmer Field Schools on Agricultural Productivity and Poverty in East Africa*. *Discussion Paper 992*. Washington, D.C.: IFPRI.

Deane, P. (1965) *The First Industrial Revolution.* Cambridge University Press.

Deininger, K. (2014) ‘Securing Land Rights for Smallholder Farmers’, in Hazell, P. & Rahman, A. (eds.) *New Directions for Smallholder Agriculture.* Oxford, UK: Oxford University Press.

Deininger, K. & Feder, G. (2009) 'Land registration, governance, and development: evidence and implications', *World Bank Research Observer 24(2)*, p233-266.

Dercon, S. & Collier, P. (2013) *African agriculture in 50 years: smallholders in a rapidly changing world?* Rome: FAO. Available at: ftp://ftp.fao.org/docrep/fao/012/ak542e/ak542e18.pdf

Dorward, A., Kydd, J., Morrison, J. & Poulton, C. (2005) 'Institutions, markets and economic coordination: linking development policy to theory and praxis', *Development and Change 36(1)*, p1-25.

Dorward, A., Kydd, J., Poulton, C. & Bezemer, D. (2009) 'Coordination risk and cost impacts on economic development in poor rural areas',.*Journal of Development Studies, 45(7)*, p1093-1112.

Doss, C. (2006) 'Analyzing technology adoption using microstudies: Limitations, challenges, and opportunities for improvement', *Agricultural Economics*, *34*, p207-219.

Evenson, R. & Gollin, D. (eds.) (2003) *Crop Variety Improvement and its Effect on Productivity*. Wallingford: CABI Publishing.

Evenson R., Pray, C. & Rosegrant, M. (1999) *Agricultural Research and Productivity Growth in India*. *Research Report No.109*. Washington, D.C.: International Food Policy Research Institute.

Fan, S. (2007) 'Agricultural research and urban poverty in China and India', in Adato, M. & Meinzen-Dick, R. (eds.) *Agricultural Research, Livelihoods, and Poverty: Studies of Economic and Social Impacts in Six Countries*. Baltimore: Johns Hopkins University Press.

Fan, S., Hazell, P. & Thorat, S. (1999) *Linkages Between Government Spending, Growth and Poverty in Rural India*. *Research Report 110*. Washington, D.C.: IFPRI.

Fan, S. & Rao, N. (2008) 'Public investment, growth and rural poverty', in Fan, S. (ed.) *Public Expenditures, Growth and Poverty: Lessons for Developing Countries.* Baltimore: Johns Hopkins University Press.

Feder, G., Just, R. & Zilberman, D. (1985) 'Adoption of agricultural innovations in developing countries: A survey', *Economic Development and Cultural Change 33(2)*, p255-298.

Feder, G. & Nishio, A. (1999) 'The benefits of land registration and titling: economic and social perspectives', *Land Use Policy 15(1)*, p25-43.

Frankel, F. (1976) *India's Green Revolution: Economic Gains and Political Costs*. Princeton, N.J.: Princeton University Press.

Freebairn, D. (1995) 'Did the Green Revolution concentrate incomes? A quantitative study of research reports', *World Development 23(2)*, p265-279.

Freeman, H., Shiferaw, B. & Swinton, S. (eds.) (2005) *Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts*. Wallingford, UK: CAB International.

Fuglie, K. (2010) 'Total factor productivity in the global agricultural economy: Evidence from FAO data', in Alston, J., Babcock, B. & Pardey, P. *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Ames, Iowa: The Midwest Agribusiness Trade

Research and Information Center, Iowa State University. Available at: http://www.card.iastate.edu/books/shifting_patterns/pdfs/chapter4.pdf

Geertz, C. (1963) *Agricultural Involution: The Process of Ecological Change in Indonesia*. Berkeley, CA: University of California Press.

Ghani, E. (ed.) (2010) *The Poor Half Billion in South Asia: What is Holding Back Lagging Regions?* New Delhi: Oxford University Press.

Goldman, A. & Smith, J. (1995) 'Agricultural transformations in India and Northern Nigeria: exploring the nature of green revolutions', *World Development 23(2)*, p243-263.

Gollin, D., Morris, M. & Byerlee, D. (2005) 'Technology adoption in intensive post-green revolution systems', *American Journal of Agricultural Economics 87(5)*, p1310-1316.

Griffin, K. (1972) *The Green Revolution: An Economic Analysis*. Geneva: United Nations Research Institute for Social Development.

Grigg, D. (1984) 'The agricultural revolution in Western Europe', in Bayliss-Smith, T. & Wanmali, S. (eds.) *Understanding Green Revolutions.* Cambridge University Press, p1-15.

Haggblade, S., Hazell, P. & Dorosh, P. (2007) 'Sectoral growth linkages between agriculture and the rural nonfarm economy', in Haggblade, S., Hazell, P. & Reardon, T. (eds.) *Transforming the Rural Nonfarm Economy*. Baltimore: Johns Hopkins University Press, p141-182.

Haggblade, S., Tembo, G., Kabore, D. Reij, C., Ajayi, O., Franzel, S., Mafongoya, P. & Place, F. (2010) 'Sustainable soil fertility management systems', in Haggblade, S. & Hazell, P. (eds.) *Successes in African Agriculture: Lessons for the Future*. Baltimore: Johns Hopkins University Press, p262-319.

Hayami, Y. & Ruttan, V. (1971) 'Factor prices and technical change in agricultural development: the United States and Japan, 1880-1960', *Journal of Political Economy 78*, p1115-1141.

Hayami, Y. & Ruttan, V. (1985) *Agricultural Development: An International Perspective (2nd ed)*. Baltimore: Johns Hopkins University Press.

Hazell, P. (2008) *An Assessment of the Impact of Agricultural Research in South Asia since the Green Revolution*. Rome: CGIAR Science Council Secretariat.

Hazell, P. (2009) 'The Green Revolution', in Spielman, D. & Pandya-Lorch, R. *Millions Fed: Proven Successes in Agricultural Development.* Washington, D.C.: IFPRI. Available at http://www.ifpri.org/sites/default/files/publications/oc64ch03.pdf

Hazell, P. (2011) *New developments in financial risk management tools for farmers. Science review: SR 22.* Foresight Project on Global Food and Farming Futures, London: Government Office for Science. Available at: http://webarchive.nationalarchives.gov.uk/20121212135622/http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/science/11-567-sr22-new-developments-financial-risk-management-for-farmers.pdf

Hazell, P. (2013) *Feed the Future Learning Agenda Literature Review: Improved Agricultural Productivity.* USAID. Available at:

http://agrilinks.org/sites/default/files/resource/files/Feed%20the%20Future_Learning%20Agenda%20Literature%20Review_Ag%20Productivity_2013.pdf

Hazell, P. & Haddad, L. (2001) *Agricultural Research and Poverty Reduction*. *Food, Agriculture, and the Environment Discussion Paper 34*. Washington, D.C.: International Food Policy Research Institute.

Hazell, P. & Haggblade, S. (1993) 'Farm-nonfarm growth linkages and the welfare of the poor', in Lipton, M. & van der Gaag, J. (eds.) *Including the Poor*. Washington, D.C.: World Bank, p190-204.

Hazell, P. & Wood, S. (2008) 'Drivers of change in global agriculture', *Philosophical Transactions of the Royal Society B 363(1491)*, p495-515.

Headey, D., Alauddin, M. & Prasada Rao, D. (2010) 'Explaining agricultural productivity growth: an international perspective', *Agricultural Economics 41(2010)*, p1-14.

Hobbs, P., Sayre, K. & Gupta, R. (2007) 'The role of conservation agriculture in sustainable agriculture', *Philosophical Transactions of the Royal Society Series B 363 (1491)*, p543-556. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2610169/

International Fund for Agricultural Development and World Food Programme. (2010) *Potential for Scale and Sustainability in Weather Index Insurance for Agriculture and Rural Livelihoods.* Rome: International Fund for Agricultural Development. Available at: http://www.ifad.org/ruralfinance/pub/weather.pdf

Jack, B. (2013) *Constraints on the Adoption of Agricultural Technologies in Developing Countries. Literature Review*. Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA (UC Berkeley).

Joireman, S. (2007) 'The mystery of capital formation in Sub-Saharan Africa: Women, property rights and customary law', *World Development 36 (7)*, p1233-1246.

Joshi, P., Jha, A., Wani, S., Joshi, L. & Shiyani, R. (2005) *Meta-Analysis to Assess Impact of Watershed Program and People's Participation. Comprehensive Assessment Research Report 8*. Colombo, Sri Lanka: IWMI.

Kerr, J., Pangare, G. & Vasudha, L. (2002) *Watershed Development Projects in India: An Evaluation*. *Research Report 127.* Washington, D.C.: International Food Policy Research Institute.

Larson, D., Anderson, J. & Varangis, P. (2004) 'Policies on managing risk in agricultural markets', *World Bank Research Observer 19(2)*, p199-230.

Lipton, M. & Longhurst, R. (1989) *New Seeds and Poor People*. Baltimore: Johns Hopkins University Press.

Locke, A. & Henley, G. (2014) *Topic Guide: Land*. UK: Evidence on Demand. Available at: http://www.evidenceondemand.info/topic-guide-land

Masters, W., Andersson Djurfeldt, A., DeHaan, C., Hazell, P., Jayne, T., Jirström, M. & Reardon, T. (2013) *Urbanization and Farm Size in Asia and Africa: Implications for Food Security and Agricultural Research*. Synthesis paper from an ISPC Foresight Study on Farm Size and Urbanization. Available at: http://www.sciencecouncil.cgiar.org/sections/strategy-trends

McDonald, A., Hobbs, P. & Riha, S. (2006) 'Does the system of rice intensification outperform conventional best management? A synopsis of the empirical record', *Field Crops Research, 96*, p31-36.

Meinzen-Dick, R., Knox, A., Place, F. & Swallow, B. (eds.) (2002) *Innovation in Natural Resource Management; The Role of Property Rights and Collective Action in Developing Countries*. Baltimore: Johns Hopkins University Press.

Meinzen-Dick, R. & Mwangi, E. (2008) 'Cutting the web of interest: pitfalls of formalizing property rights', *Land Use Policy 26(1)*, p36-43.

Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., Ragasa, C. & Beintema, N. (2011) *Engendering Agricultural Research, Development, and Extension*. *Research Monograph*. Washington, D.C.: IFPRI.

Minot, N. & Benson, T. (2009) *Fertilizer Subsidies in Africa: Are Vouchers the Answer? Issue Brief 60*. Washington, D.C.: International Food Policy Research Institute.

Mishra , A., Whitten, M., Ketelaar, J. & Salokhe, V. (2006) 'The system of rice intensification (SRI): a challenge for science, and an opportunity for farmer empowerment towards sustainable agriculture', *International Journal of Agricultural Sustainability 4(3)*, p193-212.

Moser, C. & Barrett, C. (2003) 'The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar', *Agricultural Systems 76*, p1085-1100.

Namara, R. Weligamage, P. & Barker, R. (2003) *Prospects for Adopting System of Rice Intensification in Sri Lanka: A Socioeconomic Assessment*. *Research Report 75*. Colombo, Sri Lanka: IWMI.

Omamo, S., Diao, X., Wood, S., Chamberlin, J., You, L., Benin, S., Wood-Sichra, U. & Tatwangire, A. (2006) *Strategic Priorities for Agricultural Development in Eastern and Central Africa*. Washington, D.C.: International Food Policy Research Institute.

Ostrom, E. (1994) *Neither Market nor State: Governance of Common-Poor Resources in the Twenty-First Century*. Washington, D.C.: IFPRI. Available at: http://www.ifpri.org/sites/default/files/publications/ls2.pdf

Pender, J., Place, F. Ehui, S. (eds.) (2006) *Strategies for Sustainable Land Management in the East African Highlands.* Washington, D.C.: IFPRI.

Pender, J., Scherr, S. & Durón, G. (2001) 'Pathways of development in the hillside areas of Honduras: causes and implications for agricultural production, poverty and sustainable resource use', in Lee, D. & Barrett, C. (eds.) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. Wallingford, UK: CAB International.

Peterman, A., Behrman, J. & Quisumbing, A. (2010) *A Review of Empirical Evidence on Gender Differences in Nonland Agricultural Inputs, Technology, and Services in Developing Countries. IFPRI Discussion Paper 00975*. Washington, D.C.: IFPRI.

Pinstrup-Andersen, P. (1982) *Agricultural Research and Technology in Economic Development*. New York: Longman.

Place, F., Franzel, S., DeWolf, J., Rommeise, R., Kwesiga, F., Niang, A. & Jama, B. (2002) 'Agroforestry for soil-fertility replenishment: Evidence on adoption processes in Kenya and Zambia', in Barrett, C., Place, F. & Aboud, A. (eds.) *Natural Resources Management in African Agriculture.* Wallingford, UK: CABI Publishing, p155-168.

Quisumbing, A. (1995) *Gender Differences in Agricultural Productivity: A Survey of Empirical Evidence*. *FCND Discussion Paper No. 5*. Washington, D.C.: IFPRI.

Quisumbing, A. & Pandolfelli, L. (2010) 'Promising approaches to address the needs of poor female farmers: Resources, constraints, and interventions', *World Development 38(4)*, p581-592.

Ragasa, C. & Golan, J. (2012) *The Role of Rural Producer Organizations for Agricultural Service Provision in Fragile States*. *IFPRI Discussion paper 01235*. Washington, D.C.: IFPRI. Available at: http://www.ifpri.org/sites/default/files/publications/ifpridp01235.pdf

Rao, X., Hurley, M. & Pardey, P. (2012) *Recalibrating the reported rates of return to food and agricultural R&D. Staff Paper P12-8*. Department of Applied Economics, University of Minnesota. Available at: http://ageconsearch.umn.edu/handle/135018

Ravallion, M. & Datt, G. (1996) 'How important to India's poor in the sectoral composition of economic growth?', *World Bank Economic Review 10 (1)*, p1-26.

Reij, C., Tappan, G. & Smale, M. (2009) 'Re-greening the Sahel: farmer-led innovation in Burkina Faso and Niger', in Spielman, D. & Pandya-Lorch, R. (eds.) *Millions Fed: Proven Successes in Agricultural Development*. Washington, D.C.: IFPRI, p53-58.

Renkow, M. & Byerlee, D. (2010) 'The impacts of CGIAR research: A review of recent evidence', *Food Policy 35(2010)*, p391-402.

Rezek, J., Campbell, R. & Rogers, K. (2011) 'Assessing total factor productivity growth in Sub-Saharan African agriculture', *Journal of Agricultural Economics 62(2)*, p357-374.

Rola, A. & Pingali, P. (1993) *Pesticide, Rice Productivity and Farmer's Health: An Economic Assessment*. Washington, D.C./Los Banos, Philippines: World Resources Institute/IRRI.

Sheehy, J., Sinclair, T. & Cassman, K. (2005) 'Curiosities, nonsense, non-science and SRI', *Field Crops Research 91*, p355-356.

Shiferaw, B., Okello, J. & Reddy, R. (2009) 'Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practice', *Environment, Development and Sustainability 11*, p601-609.

Sinha, S. & Talati, J. (2007) 'Productivity impacts of the system of rice intensification (SRI): a case study in West Bengal, India', *Agricultural Water Management 87*, p55-60.

de Soysa, I. & Petter Gleditsch, N. (with Gibson, M. & Sollenberg, M) (1999) *To Cultivate Peace: Agriculture in a World of Conflict*. *Environmental Change & Security Project Report, Issue 5 (summer 1999) 15*. Washington, D.C.: Wilson Center. Available at: http://www.wilsoncenter.org/sites/default/files/feature2.pdf

Susmita, D., Meisner, C. & Wheeler, D. (2007) 'Is environmentally friendly agriculture less profitable for farmers? Evidence on Integrated Pest Management in Bangladesh', *Review of Agricultural Economics 29(1)*, p103-118.

Swinnen, J. & Maertens, M. (2010) *Finance through food and commodity value chains in a globalized economy.* KfW Financial Sector Development Symposium 2010, Finance for Food: Towards New Agricultural Rural Finance. Available at: https://lirias.kuleuven.be/bitstream/123456789/290158/1/Financial_Sector_Symposium_Berlin_2010_-_Session_2_-_Jo_Swinnen_-_Paper%5B1%5D.pdf

Thirtle, C., Lin, L. & Piesse, J. (2003) 'The impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia, and Latin America', *World Development 31 (12)*, p1959-1975.

Tiffen, M., Mortimore, M. & Gichuki, F. (1994) *More People, Less Erosion: Environmental Recovery in Kenya.* Chichester, UK: Wiley.

Tripp, R. (2006) *Self-Sufficient Agriculture: Labour and Knowledge in Small-Scale Farming*. London: Earthscan.

Udry, C., Hoddinott, J., Alderman, H. & Haddad, L. (1995) 'Gender differentials in farm productivity: implications for household efficiency and agricultural policy', *Food Policy 20*, p407-423.

Uphoff, N. (2001) 'Balancing development and environmental goals through community-based natural resource management', in Lee, D. & Barrett, C. (eds.) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment.* Wallingford, UK: CAB International, p433-450.

Uphoff, N. (2003) 'Higher yields with fewer external inputs? The system of rice intensification and potential contributions to agricultural sustainability', *International Journal of Agricultural Sustainability 1(1)*, p38-50.

Wiggins, S. & Keats, S. (2013) *Leaping and Learning: Linking Smallholders to Markets*. Agriculture for Impact. London: Imperial College. Available at: https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/LeapingandLearning_FINAL.pdf

World Bank. (2007) *World Development Report 2008: Agriculture for Development*. Washington, D.C. Available at: http://siteresources.worldbank.org/INTWDRS/Resources/477365-1327599046334/WDR_00_book.pdf

World Bank. (2011) *World Development Report 2011: Conflict, Security, and Development*. Washington, D.C. Available at: http://siteresources.worldbank.org/INTWDRS/Resources/WDR2011_Full_Text.pdf