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A Selective Synthesis

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Paper prepared for presentation at the “Agriculture in A Changing Climate: The New International Research Frontier” conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra, Australia, September 3, 2008

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A Selective Synthesis

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In this summary overview of papers presented at the Crawford Fund's Parliamentary Conference, *Agriculture in a Changing Climate: the new frontier in international agricultural research*, I have been deliberately selective in synthesising elements of the presentations and for brevity I have omitted scientific references, which can be found in the foregoing contributions. Wherever possible, I have tried to draw out examples of Australian work and experience that may be relevant to the issues and to their policy and technology solutions. I have also tried to address or at least record questions and comments made by participants on the comment forms provided at the Conference and shown here in italics.

DR BLIGHT has a career including positions as a diplomat, public servant and chief executive. His association with international agricultural research began in earnest some 25 years ago when he was appointed Centre Secretary of the Australian Centre for International Agricultural Research, helping to establish ACIAR under the chairmanship of Sir John Crawford. He took up his current position as Executive Director of the Crawford Fund in February 2008, having retired as Director-General of CAB International, an intergovernmental body in research, training and publishing in the life sciences. Before that he spent 15 years with IDP Education Australia, the international development program of Australian universities and colleges, including the position as Chief Executive. Dr Blight is a consultant to CABI, chair of the Board of LIS Pty Ltd (see www.studylink.com), an advisor to the Graduate Insight Group (see www.i-graduate.org) and a member of the UK's Commonwealth Scholarships Commission.

The truth about climate change, and its impact on agriculture

The Conference more or less took as a fact an anthropogenic contribution to climate change and its impact, although qualifications on its extent and importance were registered. Ross Garnaut, whilst demonstrating little doubt about the reality of climate change said he faced:

... a lot of reluctance of people in the scientific community to chance their hand at estimates of parameters that were really rather fundamental to building up an overall view of climate change impacts in Australia. Its not part of the culture of our scientific community to answer questions of a precise kind about probability distribution until there is a high degree of certainty about the answer.

Observing the phenomena from an immediate Australian perspective, Tony Bourke interpreted the advice that he had as suggesting:

It's not simply a case of cyclical drought in some countries. The droughts are getting longer, they are getting deeper and the interval between one drought and the next is not nearly as long as it used to be.

Kathy Sierra probably expressed a consensus view when she said:

Extreme weather, major changes in precipitation patterns, droughts and flooding will increase in coming decades and will have a major negative impact on land-production systems in some regions. Rising temperatures will create heat stress in some species of livestock and less stable crop yields, and lead to more frequent outbreaks of pests and disease. This will further complicate our efforts to control diseases, including those which are passed directly from livestock to humans and those which move from wildlife to livestock to humans.

Pasture production and grazing lands will also be affected, and the competition between crops for food versus feed, already being felt, could be exacerbated.

The relationship between *climate change and pests and diseases* was further underlined in Trevor Nicholls' presentation. Using the case of Siam weed to illustrate the point, he cited predictions of CLIMEXTM, which uses IPCC models plus precipitation, vapour pressure and temperature data to project climate change surfaces for global weeds, including Siam weed:

CLIMEX predicts that in Australia ... [Siam weed's] potential range will extend south into coastal New South Wales by 2080, and in West Africa that the range will expand east to Central Africa and beyond. While there have been some bio-control attempts in Papua New Guinea and in Ghana, this method is contentious in West Africa where many farmers perceive Siam weed positively as it out-competes the more difficult-to-manage *Imperata cylindrica*.

So while Siam weed may have some redeeming qualities, it has other complex impacts. It is an attractant for the African grasshopper *Zonocerus variegatus*, which sequesters the pyrrolizidine alkaloids of *C. odorata*, protecting itself from antagonists and increasing its population. *Zonocerus variegatus* is polyphagous, defoliating maize, cassava and other food crops, particularly during the dry season. Increases in *Z. variegatus* populations have been linked with the increasing cover of Siam weed in West Africa. As well as being a pest in its own right, it transmits cassava bacterial blight, one of the major cassava diseases in the region.

Frances Seymour warned that *forests* are also a casualty of climate change:

Forests are vulnerable to the extreme weather events that are likely to become more frequent with climate change. The mitigation potential of forests could itself be affected. A warmer, drier climate could trigger a positive feedback loop that results in the dieback of forests, and thus increased emissions and further warming. In other words, warmer, drier weather could lead to a vicious circle in which increased incidence of burning renders forests less able to recover and sequester carbon in forest vegetation, which in turn would accelerate climate change.

There is little doubt in Shaun Coffey's view that climate change is a serious issue for *livestock production*:

Climate change impacts on animal production are manifested mainly at a regional level, and could be more readily addressed were it not for the fact that livestock production also contributes significantly to the problem itself.

Similarly the critical roles that animals play in poverty reduction and development in transition and less developed economies cannot be ignored. The resultant increases in demand will result in continued growth of GHG emissions globally.

Given the present state of knowledge, it is not possible to envisage an industry program that would contain and reduce global emissions from animals without seriously compromising the aspirations of developing nations and the rural poor. Further improvements in productivity will be achieved, but recent evidence suggests these will not keep pace with growth in total production in the sector.

Rob Lewis drew attention to the climate change impacts on *aquaculture and fisheries*:

Extreme weather events are intrinsically linked to the climate change regimes and influences. The warming and consequential increase in ocean heat content, thermal expansion and reduction in land-based ice are seen as contributory factors driving these phenomena. Extreme events include intensified precipitation and droughts; monsoonal, cyclonic and hurricane activity; storm surges and flooding; as well as temperature shocks. Extreme events can manifest themselves through both increased frequency and or severity. Extreme events occur on a global scale as seen from cyclonic events, or on a local scale as the Australian southern bluefin tuna farming industry experienced in 1996 when more than 95% of the standing production was wiped out by a localised high-intensity event.

Climate change has the potential to strengthen upwelling events, enhancing nutrient input to receiving regions. This is predicted to have both adverse and positive effects. Adverse effects include disruption of the bio-rhythms and processes of key species, whilst pluses are predicted to include increased regional productivity from the additional nutrient inputs.

According to Mark Howden:

... climate change is happening faster than expected, with the four key global indicators (greenhouse gas emissions, atmospheric carbon dioxide concentrations, global temperature and sea-level rise) all at or above the 'worst case' scenario developed by the IPCC about a decade ago.

Segenet Kelemu said the *African continent* is particularly vulnerable to climate change because it consists of some of the world's poorest nations.

The climate in Africa is largely tropical in nature, which is classified into three major climatic zones: humid equatorial, dry and humid temperate.

Within these zones, however, altitude and other localised variables generate distinct regional climates. Climate change, especially manifested by prolonged drought, is one of the most serious climatic hazards affecting the agricultural sector of the continent. As most of the agricultural activities in the majority of African countries are rain-fed, any adverse changes in the pattern and amount of precipitation would have a devastating effect on the sector in the region, and on the livelihood of most of the population. Variability is expected to increase, including frequent occurrences of extreme events particularly in marginal rainfall areas.

Drought is perhaps the most dramatic limiting factor to crop and animal production on a global scale, and the situation is expected to deteriorate in Africa. The current trends in land degradation, desertification and climatic variability have been predicted to intensify. The erratic rainfall across seasons, poor soil-water-holding capacity and poor management of water resources have led to drought occurring frequently. In the last two decades, droughts occurred in 1983–1984, 1991–1992, 1995–1996, 1999–2001 and 2004–2005 in parts of Africa with significant impact on human, animal, vegetation and other resources. The debate on climate change and its impacts on agriculture are, therefore, crucial to the very survival of the African continent and its people.

But the impact of climate change is uncertain. As Kathy Sierra put it:

... the impact of climate change is not always certain — and not always negative. There is some evidence that higher atmospheric concentrations of carbon dioxide could actually increase plant growth and improve water use efficiency, particularly in wheat, rice, soybeans and potato. These results have not yet been verified in the field, where limiting factors such as pests, soil and water quality, and crop–weed competition exist.

Similarly, Mark Howden placed the relative impact of climate change in the broader context of economic and social development when he referred to studies that showed:

... globally, impacts of climate and CO₂ increase are small compared with the positive effects of socio-economic development paths, with substantial regional variation. For example, climate change alone is estimated to increase the number of undernourished people in 2080 by 5–10 million under [one] scenario, up to 120–170 million people under [another] scenario or by ±30 million. In terms of regional disparity in food availability, for a high-emissions scenario, 42 developing countries may benefit from substantial increases in cereal production (averaging 17%) by 2080 whereas 52 countries with a population of up to 3 billion may lose on average 19% of their current yield potential over the same period.

In a review of global food security studies, [one report] suggested that the robust economic growth projected for the 21st century will (in all but [one] scenario) significantly reduce the number of people at risk of hunger in 2080 ... because real incomes are likely to rise faster than real food prices, thereby increasing access to food. Average price variations expected from the effects of global change are much smaller than those from socioeconomic development paths.

Nevertheless, Howden worries that analyses of global food security may significantly understate the challenge arising from climate change and that effective adaptation technologies, management options and policies are not keeping pace with climate change. He also highlighted other factors: crop yield growth is declining; the availability of water for irrigation is under pressure from lower rainfalls and higher temperatures; increased fuel and fertiliser costs; land degradation; and policy and market constraints. This last point included policies to reduce emissions of greenhouse gases.

A related written comment by a participant warned that climate change adaptation measures could, unless we were careful, actually aggravate climate change.

The last word on the overall impact of climate change, however, might be left to the concluding speaker, Ross Garnaut. Talking of the Australian context and the review of climate change, which he led, Garnaut concluded:

It's not going to be all negative and all challenges. ... There will be some regions with access to enough water to productively use the increased carbon dioxide in the atmosphere to increase

yields — at least for a while. Eventually, however, temperatures will increase too much.

We had a careful study of that done for the review, but most of the effects on production will be of a negative kind.

The contribution of agriculture to climate change

Agriculture is, and will remain, a contributor to climate change. It is a major user of land and water resources, and a significant source of greenhouse gases — an estimated 10–12% of all GHG emissions resulting from human activity.

Expansion of the agricultural frontier through land clearing and slash-and-urn contributes even more, with the total impact of land use and forestry changes contributing almost one-third of GHG emissions in all developing countries.

As Francis Seymour pointed out:

Deforestation and forest degradation are now recognised to be a globally significant source of greenhouse gas emissions, and it is asserted that reduction of forest-based emissions may be among the least expensive mitigation options. However, decades of unsuccessful efforts to reverse high rates of deforestation and degradation in the tropics have revealed the fundamental failures of markets, governance and policy that drive forest loss. New initiatives toward ‘Reducing Emissions from Deforestation and Forest Degradation’ (REDD) will face similar challenges, but could bring to bear new sources of finance and political will.

In commenting on what was described as an excellent presentation by Francis Seymour, one participant asked about the prospects for an international system of environmental services payments to ‘local people responsible for maintaining biodiverse forests?’

The relationship between livestock and climate change is also complex as Shaun Coffey noted:

A common feature of many developed nations is that GHG emissions from agriculture have been falling. Some developed countries, however, have not followed this trend. In New Zealand, GHG emissions from agriculture, in particular nitrous oxide and methane from pastoral or agricultural activities, have been rising at about 1% per year since 1990. Emissions growth has come first from increased individual animal production (meaning each animal consumes more forage and thus produces more methane and excretes more nitrogen). Second, this increased feed

consumption has required growth in the use of inorganic nitrogen fertiliser from 52 000 t in 1990 to 345 000 t in 2005. But, while the total amount of GHG from NZ has increased, the amount emitted per unit of production has declined by about 17%.

A participant from the Crawford Fund’s Victorian Committee asked whether the reduction in sheep numbers in Australia and reduced tillage in crop production was a major factor in greenhouse gas reductions, possibly the only sector in Australia to see such a fall.

Complexity is compounded by conundrum. According to Coffey:

... the critical roles that animals play in poverty reduction and development in transition and less-developed economies cannot be ignored. The resultant increases in demand will result in continued growth of GHG emissions globally.

Might not the answer lie, asked one participant in a written comment, in a reconsideration post Kyoto of the treatment of emissions from ruminants that were in any case largely derived from cellulosic ingredients?

These complex interactions between agriculture and climate change, highlighted in the foregoing abstracts from Conference presentations, indicate that adaptation to the impacts of climate change and mitigation are both important. We must, it was argued in several papers, accelerate our search for new knowledge, policies and technologies in both areas. Indeed there is an opportunity to exploit the significant synergies between adaptation and mitigation in agriculture to counter increased risks of climate change impacts.

Whilst the emphasis was on technology, the social dimensions of the relationship between climate change and agriculture were not ignored. Farmers, fishers, foresters and herders in the 21st century will need to overcome significant challenges. These will arise largely from the need to increase the global food and timber supply for a world growing to 10 billion people or more, while adjusting and contributing to responses to climate change.

Agricultural research priorities

As Executive Director of the Fund, I was naturally pleased at the acknowledgement of the work of the Crawford Fund’s founding director, Professor Derek Tribe. No one, it was said, showed a better

grasp of the central importance of agricultural research than he. His 1994 book, *Feeding and Greening the World*, charted a clear path forward. Yet, just as the journey was getting under way, stagnating support for agricultural research for development drastically slowed its progress.

In making these points, Kathy Sierra added that the results of flattened growth in agricultural research funding and faltering investment in rural development have been made dramatically evident in the past few months as the international community deals with a global food prices crisis. While there were, and remain, multiple factors that led to the crisis — as reported for example in the 2008 Crawford Fund report, *A Food Secure World; how Australia can help*, a fundamental element was the lack of capacity to supply more food when the world demanded it.

Another Australian acknowledged during the conference was Lloyd Evans. His ‘haunting and informative book’, *Feeding the Ten Billion*, was an inspiration to Cary Fowler who cited Evans’s analysis of different moments in human history and the ways in which people procured or produced food changed as the population grew, and as the technology and environment changed. Lloyd Evans had pointed out that historically the most significant way has been to cut down trees to expand cropland. Globally, this is becoming less of an option and attention is drawn once again to enhancing crop and animal productivity.

Kathy Sierra was undoubtedly right, therefore, when she said that there is now a heightened awareness among many decision-makers that it was an error to have neglected, soon after the Tribe and Evans publications, investment in agriculture research for so long. There is also, as she said, a greater realisation that agriculture’s many value chains for food, feed, fibre and industrial uses all depend on research-based innovation. This was also certainly one of the main messages of the World Bank’s *World Development Report 2008: Agriculture for Development*, which detailed how much this lack of investment, and lack of interest, in agricultural research has cost.

One or two participants, in their written commentaries, described continuing population growth as ‘the root cause’ of food shortages and that that limits on growth, and how this might be achieved, were a priority for research and policy attention.

Kathy Sierra outlined the following priority areas, upon which I have expanded to take into account comments of others including in particular those by Peter Core:

- research to enhance the hardy varieties already available. Tolerance to stresses such as drought, heat and high salinity must be combined with other valuable traits, such as better nutritional quality. Peter Core expressed this area of work in another way as stress-tolerant crop cultivars, citing work by CIMMYT combining the latest in molecular biology with farmer participation trials prioritising major stresses to maize — drought, low soil fertility, insect pests and poor soils. He referred also to similar work on wheat and the development of new rices for Africa. He said that this work was being done on a ‘shoe string’ but deserved overwhelming priority
- an increased flow of hardier varieties for a wider range of staple crops. Rice, wheat and maize are critically important and should, according to Peter Core, be accorded priority. But the poor also depend on many other cereals, as well as roots, tubers and grain legumes. Shaun Coffey (and Derek Tribe) would no doubt remind us of the important role of livestock in poverty reduction.
- a more determined push to apply powerful new tools from molecular biology. Molecular genetic maps, for example, together with crop performance data from diverse sites, are critical for identifying areas of crop genomes that are linked to stress tolerance. This must go hand-in-hand with more vigorous evaluation of plant genetic resources. The traditional varieties and wild relatives being conserved are a rich source of genes needed to enhance stress resistance. To date, however, only about 10% of the 600 000 plant samples held in CGIAR gene banks have been characterised.
- In her presentation, Segenet Kelemu was more specific when she noted that the potential role of agricultural biotechnology, particularly genetically modified crops and animals, in improving the livelihoods of the poor was being debated vigorously. (*Indeed, as if to underline this point, one participant in a written comment asked whether we were caught up in this ‘high tech’ science without considering the totality of natural resource management.*) Many biotechnology products

are, she said, being developed in various countries for different uses. These products include modified plants for food and fiber, animal feed, medical care and bioremediation. She did not wish to imply that agricultural biotechnologies would, single-handedly, solve Africa's agricultural production constraints and make Africans self-sufficient in food, or completely solve the impacts of climate change. While recognising the potential, genetically modified crop varieties — just like those developed through conventional breeding strategies — must be combined with other appropriate and optimal management practices for satisfactory production. *[This issue was the main focus of the written questions and comments from participants who queried what they described as an emphasis placed by some speakers on genetic manipulation as a silver bullet.]*

- a focus on under-utilised crops. To adapt effectively to climate change, rural people will need to draw on an even wider range of biological diversity. That is why stronger efforts must be made to explore the commercial and food security potential of under-utilised plants, such as tropical fruits, medicinal herbs, and certain agro-forestry species. These plants can play an important role locally in the diets and livelihoods of the poor.
- Peter Core singled out water where he emphasised work on the public policy framework characterising the issue as a 'tragedy of the commons.' He cited work by IFPRI and IWMI.

Perhaps an over-arching priority is for what Kathy Sierra described as an integrated approach, based on prudent management of crops, livestock, fisheries and forestry and their genetic resources, and including management of soil and water. This requires complex, knowledge-intensive research. We also need to take full advantage of income-generating opportunities for farmers and other workers right along the production and delivery chain to adapt technology to local conditions and to add value. The returns to such local adaptation are substantial, as illustrated (for example) by the spread of minimum tillage in South Asia's rice and wheat systems where it was necessary to design and build small, locally-adapted machines to replace the large machinery available from developed countries.

So accurate and timely diagnosis is important. Policy and technical issues in relation to slowing deforestation, covered in the presentation by Francis Seymour when she spoke of the fundamental failures of markets, governance and policy, deserved priority according to Peter Core. Trevor Nicholls added that developing models to project the potential distribution and abundance of a pest species under various climate change scenarios is essential, and the Australian scientific community has been at the forefront with the development of CLIMEX and its application to modelling some of the world's worst weed species, such as the pan-tropical Asteraceae, *Chromolaena odorata*.

Crop diversity, according to Cary Fowler, is going to be the canary in the coal mine because it is the biological pre-requisite for adaptation and improvement. Rescuing collections that are in bad shape — principally in developing countries — is a priority. Through the work of the global crop diversity trust between 100 000 and 150 000 distinct crop varieties will be rescued in the next couple of years.

Segenet Kelemu agreed, noting that plant and animal genetic resources are also vulnerable to adverse changes in climate, thus potentially depriving Africa and the rest of the world of this natural wealth. *One participant in written comments, whilst acknowledging the importance of seed (gene) banks, asked why less support was given in the formal presentations for domestic animals, which were also a priority, especially for Africa.*

Touching on the need for better information systems, one participant in a written comment noted that information collected on individual seeds if made available could enable the seeds to be grown successfully by a wider range of users.

Another participant, in a written comment, lamented the absence of a national seed bank in Australia, and the declining funding for the 200 000 seed accessions in five agricultural seed-banks collected over 60 years from 130 countries. The participant noted that Australian pasture seed collections were a particularly valuable and unique resource at risk.

According to Howden, the ‘volatility of production and prices should be a core part of future assessments of global food security alongside more traditional analyses of food availability.’ It also ‘raises the question as to whether new assessment methods are needed. For example, partial equilibrium economic models could be used instead of general equilibrium models to incorporate the impact of climate variability on food production.’ There is, in Howden’s view:

... a clear need to increase investment into research of the biophysical, economic and institutional factors limiting growth in grain yields. More integrated, systems research that includes genetics, management, policy and communication could open pathways to yield

improvements that are closed to more traditional reductionist approaches. This could enable research to transcend the natural limits of single-factor research. These new integrated methods for assessing global food security need to be able to incorporate the new policies, constraints and opportunities associated with climate change, such as emissions restrictions and the emerging carbon economy. This may require more of a bottom-up approach including social, economic and cultural dimensions, and scaling these up to regional level. A stronger focus on managing climate variability is likely to deliver useful information and technologies at farm and community scales that can reduce supply and price fluctuations and be transferred between regions. Lastly, consideration needs to be given to collective action to build the livelihood options and risk management capacity of vulnerable groups to deal with climate change.

Three final written comments may be worth recording because they foreshadow possible future Crawford Fund Conference topics. The first related to application and communication of research outcomes. The second concerned questions of gender that had been ‘completely neglected’ in most presentations. And the third focused on the inter-relationships between publicly funded research organisations and the transfer of their intellectual property outputs to private multinational corporations.

Other Crawford Fund Publications since 2001

- Brown, A.G. (ed.) 2001. *Prosper or Perish: Asian Poverty and the Australian Economy*. Record of a conference conducted by the Crawford Fund for International Agricultural Research, Parliament House, Canberra, 28 June 2001. iii + 58 pp. ISBN 1 875618 67 8
- Brown, A.G. (ed.) 2002. *Pathways to Sustainable Forest Management*. Proceedings of the second Hermon Slade International Workshop, Ubud, Bali, 5–8 June 2001. The ATSE Crawford Fund, Parkville, Vic. iv + 88 pp. ISBN 1 875618 72 4
- Brown, A.G. (ed.) 2002. *Food for the Future: Opportunities for a Crowded Planet*. Record of a conference conducted by the ATSE Crawford Fund, Parliament House, Canberra, 8 August 2002. The ATSE Crawford Fund, Parkville, Vic. iv + 88 pp. ISBN 1 875618 74 0
- Crawford Fund 2003. *A Catalyst for Change: International Agricultural Research: An Introduction to the ATSE Crawford Fund*. The Fund [Parkville, Vic.] 16 pp.
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- Nairn, M.E., Henzell, E.F. and Williams, M.J. 2004. *Building on Success*. Report and recommendations of an independent review of the ATSE Crawford Fund, March 2004. ATSE, Parkville, Vic. 98 pp.
- The ATSE Crawford Fund 2005. *Healing Wounds: An Australian Perspective*. Research that rebuilds agriculture after conflicts and natural disasters. The Fund, Parkville, Vic. 14 pp.
- The ATSE Crawford Fund 2005. *Report 1 January 2004 to 30 June 2005*. The Fund, Parkville, Vic. 25 pp.
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- Brown, A.G. (ed.) 2007. *Water for Irrigated Agriculture and the Environment: Finding a Flow for All*. Record of a conference conducted by the ATSE Crawford Fund, Parliament House, Canberra, 16 August 2006. The ATSE Crawford Fund, Parkville, Vic. vi + 72 pp. ISBN 1 875618 92 9.
- Anon. 2007. *The ATSE Crawford Fund Report 1 July 2006–30 June 2007*. The Fund, Parkville, Vic. 28 pp. <http://www.crawfordfund.org/publications/pdf/annualreport2007.pdf>
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- Persley, G.J. and Blight, D.G. (eds) 2008. *A Food Secure World: How Australia can Help*. Report of the Crawford Fund World Food Crisis Task Force, Australian Academy of Technological Sciences and Engineering (ATSE), Melbourne, 60 pp. ISBN 978-1-921388-00-2.
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- The Crawford Fund newsletter, *Highlights*, is available from the Fund's website (<http://www.crawfordfund.org/index.htm>) or in printed form. In 2008, two issues were published.
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- The publications below discuss the global setting for international agricultural research. The website of the Cooperative Group for International Agricultural Research (CGIAR) (<http://www.cgiar.org/>) provides other information.
- Alston, J.M., Pardey, P.G. and Taylor, M.J. (eds) 2001. *Agricultural Science Policy: Changing Global Agendas*. John Hopkins University Press, Baltimore, 285 pp. ISBN 0 8018 6603 0
- Pardey, P.G., Alston, J.M. and Piggott, R.R. (eds) 2006. *Agricultural R&D in the Developing World: Too Little, Too Late?* International Food Policy Research Institute, Washington DC. Available for download from <http://www.ifpri.org/pubs/books/oc51.asp>
- World Bank 2007. *World Development Report 2008: Agriculture for Development*. World Bank, Washington, D.C. xviii + 365 pp. <http://econ.worldbank.org> ISBN: 9780821368077