WORLD FOOD SECURITY

2009

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CAN PRIVATE SECTOR R&D FEED THE POOR?

Record of a conference conducted by the Crawford Fund
Parliament House, Canberra, 27–28 October 2009

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CAN PRIVATE SECTOR R&D FEED THE POOR?

The Crawford Fund
Fifteenth Annual International Conference
Parliament House, Canberra
27–28 October 2009

Editor A.G. Brown

The Crawford Fund

An initiative of the Australian Academy of Technological Sciences and Engineering

Mission

To increase Australia's engagement in international agricultural research, development and education for the benefit of developing countries and Australia

The Fund

The Australian Academy of Technological Sciences and Engineering established The Crawford Fund in June 1987. It was named in honour of Sir John Crawford, AC, CBE, and commemorates his outstanding services to international agricultural research. The Fund depends on grants and donations from governments, private companies, corporations, charitable trusts and individual Australians. It also welcomes partnerships with agencies and organisations in Australia and overseas. In all its activities the Fund seeks to support international R&D activities in which Australian companies and agencies are participants, including research centres sponsored by, or associated with, the Consultative Group on International Agricultural Research (CGIAR) and the Australian Centre for International Agricultural Research (ACIAR).

Good news is worth sharing, and the Fund's Public Awareness Campaign — of which its annual Parliamentary Conference is a key feature — increases understanding of the importance and potential of international agricultural research, its achievements and needs.

And the results of research should be extended to as wide a set of users as is possible. With this objective, the Fund's Training Program and Master Classes fill a niche by offering practical, highly focused non-degree instruction to men and women engaged in the discovery and delivery of new agricultural technologies, farming practices and policies in developing countries.

The office of the Fund was transferred from Parkville in Melbourne to Deakin in Canberra at the beginning of 2009.

More detail is available at http://www.crawfordfund.org

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ACIAR — the Australian Centre for International Agricultural Research

AusAID — the Australian Agency for International Development

Australian Government Department of Agriculture, Fisheries and Forestry

AVRDC — the World Vegetable Centre

Bill and Melinda Gates Foundation

CIMMYT — the International Maize and Wheat Improvement Center

CSIRO Livestock Industries

GRDC — the Grains Research and Development Corporation

IFDC — an International Centre Creating Food Security and Agricultural Sustainability

Industrial Research Limited

ICRISAT — the International Crops Research Institute for the Semi-Arid Tropics

Monsanto

Pioneer Hi-Bred, A DuPont Business

RIRDC — the Rural Industries Research and Development Corporation

Syngenta Crop Protection

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Foreword

THE HON. NEIL ANDREW

The Crawford Fund's 2009 Parliamentary Conference focused on the potential role of private-sector research and development in helping feed the world's poor. The conference proceedings are outlined in this report.

While there are sound examples of private-sector research and development contributing positively to food production in the developing world, the conference found it difficult to quantify its overall impact. It was, however, strikingly evident that the long-term objective of increased food production, outlined in the millennium development goals, will only be met through maximised cooperation between the public and private sectors. Such partnerships are imperative. The other imperative that emerged from the conference was the importance of increased outlays on agriculture research and development at both public and private levels.

THE HON NEIL ANDREW was brought up in the SA Riverland, where his family and later Neil had interests in horticulture. He was an active participant in the SA Agricultural Bureau movement, and was Chairman 1980–1982. In 1975, he was awarded a Nuffield Agricultural Scholarship to make an overseas study tour. In 1983, he was elected to the Australian Parliament as the member for Wakefield in the House of Representatives. With changes in the boundaries of his electorate, he later moved to Gawler. He held various positions including that of Government Whip from 1997, and from November 1998 became Speaker of the House of Representatives. Neil retired from that position and from his seat in November 2004. He now lives in Adelaide and became Chairman of the Crawford Fund on the retirement of The Hon. Tim Fischer in June 2005.

Obviously, success requires a supportive policy framework and public–private partnerships of the kind described at the conference and recorded in these proceedings. The conference played a key role in jettisoning stereotypes and allowing delegates to witness the concern that the scientific staff and the leadership of large corporations showed for meeting world food production targets. Speakers from a wide range of private-sector and public-sector organisations played a key role in the conference outcomes. All presentations were well received. The effective application of new agricultural production techniques is currently being limited by a lack of extension capability. Crawford Fund training programs attempt to address this and the growing private-sector engagement in seed distribution and advisory services described by speakers from international agricultural research centres is also encouraging.

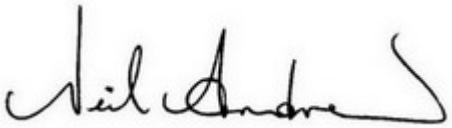
There was a lot that was new about the conference in 2009. For the first time we integrated the seminar component of the event with the dinner and the so-called Parliamentary Breakfast, opening the latter two to all participants. We also introduced a modest registration fee to partially offset the cost of the event, including the dinner and breakfast. It is informative to note that this had minimal impact on participant numbers and seemed to ensure that everyone stayed throughout the seminar. Another innovation in 2009 was the extended panel discussions which concluded the seminar component of the conference and allowed questions from the floor to be collated and answered sequentially.

The Conference is possible only because of the generous support of our sponsors. A full list of sponsors is incorporated in these proceedings but I should like to express my thanks to those who

have provided sustained support for the conference since its inception some 20 years ago and to the sponsors who have joined us for the first time.

Finally, I should like to express my personal appreciation of the time and effort invested by all of our speakers in making the event such a success. In particular, I would wish to thank Foreign Minister the Hon. Stephen Smith and Parliamentary Secretary for International Development Assistance the Hon. Bob McMullan for their contributions. Minister Smith's spontaneous endorsement of applied agricultural research as part of Australia's aid program was especially appreciated by our international guests. Similarly, Mr McMullan in his Sir John Crawford Lecture linked agricultural research and economics — the two great strengths of Sir John himself — in a very positive way

Watch for our announcement of the 2010 conference topic and timetable.



The Hon. Neil Andrew AO
Chairman
Crawford Fund Board of Governors

World Food Security

THE HON. STEPHEN SMITH MP
MINISTER FOR FOREIGN AFFAIRS

Sir John Crawford was a great Australian who was focussed on the good Australia could do in the world to help the poor and the hungry.

It is an honour to open this year's Crawford Fund Conference as we continue to work towards those same goals.

The global food security crisis is far from over. Food prices have come down since 2008 but they remain high. Poor households in developing countries, who often spend 70% of their income on food, continue to suffer. A billion people, one in every seven on our planet, go to bed hungry. When faced with these facts, good international citizens must respond and act together.

Australia is committed to being a good international citizen. Australia is the 15th largest economy and we will continue to play our part to help those less fortunate.

STEPHEN SMITH was sworn in as Minister for Foreign Affairs on 3 December 2007; he was previously the Shadow Minister for Education and Training. A barrister and solicitor by profession, he completed his Bachelor of Arts and Bachelor of Laws at the University of Western Australia, and a Master of Laws at London University, subsequently teaching law in London. During 1991 and 1992, he was Special Adviser to the Prime Minister and Senior Adviser to the Deputy Prime Minister and Treasurer, Paul Keating. He has been the Federal Member for Perth since March 1993. During 1996 and 1997, Mr Smith served as a member of the Parliamentary Joint Standing Committee on Foreign Affairs, Defence and Trade.

To address food security we must respond on several levels:

- humanitarian assistance to those in the most severe need
- development assistance, including through the strengthening of markets
- scientific research to increase crop and live-stock production
- action on developing country access to international markets by dismantling the barriers that distort trade in agricultural products. This will lead to better-functioning markets and more stable prices.

The international community, with the wake-up call of the 2008 food security crisis, recognises that we all have a stake in food production.

Like so many of the challenges we face today, food security can only be addressed effectively by nations acting together. Australia is strongly committed to international cooperation through both regional and multilateral approaches to these common challenges.

Last year, G8 leaders adopted an ad hoc statement on food security at the Hokkaido Summit. This year, at the G8 meeting in Italy, 40 states and international organisations approved the L'Aquila Initiative on Global Food Security. G20 leaders have focussed on food security and committed to provide the US$20 billion pledged at L'Aquila to increase funding for agricultural development.

This is an edited version of the Minister's speech

Last month in New York, I presented a case for greater multilateral involvement in food security at a ministerial-level forum at the UN General Assembly hosted by UN Secretary-General Ban Ki-moon and US Secretary of State Hillary Clinton.

In the early days of the food security crisis last year, Australia made prompt and generous contributions to key multilateral agencies. In May 2008 we provided $50 million for the World Bank's food security crisis response program and $30 million for the World Food Programme's special appeal. To further cement Australia's commitment, yesterday I signed a four-year $180 million Strategic Partnership Agreement with Ms Josette Sheeran, Executive Director of the World Food Programme (WFP).

The WFP is the largest and most effective international food aid organisation. Ms Sheeran told me that, at any time, WFP only has enough funding certainty for 12 weeks of operations, making it very difficult to plan ahead and buy food at the best possible price. Through the partnership, the first of its kind between a donor country and the WFP, Australia will provide long-term guaranteed funding to the WFP to enhance its ability to plan for both crisis and longer term humanitarian feeding programs. I am particularly pleased that $40 million under the new partnership will be dedicated to school feeding programs in Asia, Africa and Latin America.

In our meeting we discussed Australia's comprehensive approach to tackling hunger. Ms Sheeran was kind enough to describe Australia as a 'model donor' and she expressed the hope that other countries would follow Australia's lead on prompt, generous and flexible responses to global hunger.

The food security crisis of 2008 brought into stark focus not only the fragile state of global food security but also the decline in our focus and our effort, globally, on agriculture and agricultural research. In the last three decades agriculture's share of overseas aid has declined from 17% to less than 4%.

Australia was no exception, but in this year's Budget the Government set out to redress this. We announced increased funding for Food Security through Rural Development of $464 million over four years. A key objective of this funding is to lift research to boost agricultural productivity because with growing populations and declining availability of land, increasing agricultural productivity is vital.

We will increase funding to the Consultative Group on International Agricultural Research and continue to play a very active role in its reform process.

In the Budget the Government also delivered a substantial funding increase for ACIAR. ACIAR's funding will grow from around $64 million this year to more than $87 million by 2012–2013. This money will be well used in the interests of feeding the world's poor.

Internationally, Australian agricultural research is held in high regard — thanks to the work of organisations such as the Crawford Fund, ACIAR and AusAID. Unfortunately, this is not nearly so well understood in Australia.

A substantial portion of the Government's food security initiative will go towards work in Africa. We are committed to increasing Australia's involvement with Africa where Australian agricultural researchers have a great deal to contribute. We will be doing more to support Africa's efforts to feed its people and to extend trade through regional market integration. Whether in Africa or generally, food security is not just about the supply of food. It is also about poor people's ability to purchase food.

The task of feeding billions of people is huge, but we can do it if we think creatively and work collectively; this Conference is an excellent forum for sharing ideas.

I thank you for investing your time in contributing to its success.

Can Private-Sector R&D Reach Small Farms?

MARCO FERRONI[A]

Syngenta Foundation for Sustainable Agriculture

Millions of small farmers are reached commercially every day as they buy seeds and crop protection products, fertiliser, cell phones, machinery and tools, taking advantage of the science and research embodied in these products. The market for agricultural inputs is large, and the role of the private sector as a purveyor of technology and services is growing. It is in the nature of the private sector to bring products to the market and deliver value, including to small farmers. But the private sector goes where there is a commercial incentive. Farmers who are too poor to purchase inputs are not helped, and the technologies they need may not get developed. This is a public policy and societal challenge that cannot be solved by the public or the private sector alone. The solution requires the creative complementarities of public–private cooperation that — in addition to the farm population — must include the 'third' or not-for-profit sector (foundations, NGOs, civil society). This pathway can develop and deliver solutions to large numbers of small farmers.

DR MARCO FERRONI, an expert in international agriculture and sustainability issues, joined the Syngenta Foundation as its Executive Director in 2008. Formerly, as a Deputy Manager of the Sustainable Development Department of the Inter-American Development Bank (IDB), he had responsibility for regional sector policy and technical support to the Bank's country departments. As the Principal Officer in the Bank's Office of Evaluation and Oversight, he directed evaluation studies. As a senior advisor at the World Bank, he advised on donor relations and directed work on international public goods. Earlier in his career, he was an economist in the government of Switzerland, working in development cooperation. He holds a doctoral degree in agricultural economics from Cornell University. He has worked in Latin America, Africa and Asia.

Introduction

The theme of the Crawford Fund's 2009 Annual Development Conference — *World Food Security: Can Private Sector R&D Feed the Poor?* — continues to be relevant and timely. World food security is a distant dream. Donors have reacted to the recent food price crisis by promising increased support to agriculture — notably in Sub-Saharan Africa and South Asia where crop yield shortfalls are pronounced. But ultimately it is the private sector that must deliver inputs to the farmers. Can private R&D and distribution channels reach small farmers, the group that produces most of the food consumed in less developed countries and emerging markets?

The answer is straightforward: millions of small farmers are reached commercially every day as they buy seeds and crop protection products, fertiliser, cell phones, machinery and tools, taking advantage of the science and research embodied in these products. The market for agricultural inputs is large, and the role of the private sector as a purveyor of technology and services is growing. It is in the nature of the private sector to bring products to the market and deliver value, including to small farmers. But the private sector goes where there is a commercial incentive and a business case where money can be made. Farmers who are too poor to purchase inputs are not helped, and the technologies they need may not get developed.

[A] Comments by colleagues at Syngenta Foundation for Sustainable Agriculture are kindly acknowledged. Special thanks and recognition go to Vivienne Anthony, Mike Robinson and Yuan Zhou for their contributions. The usual disclaimers apply.

This is a public policy and societal challenge that cannot be solved by the public or the private sector alone. It requires public–private cooperation that — in addition to the farm population — must include the 'third' or not-for profit sector (foundations, NGOs, civil society). Cooperation offers the prospect to overcome each sector's limitations: the business sector's inability to operate where there is no market; the not-for-profit sector's tools and interventions that tend to take the form of projects that can reach only relatively small numbers of farmers; and the public sector's limited ability to market research outputs.

Clearly, public agricultural research is important and there is a large literature on its impact. The benefits include spillovers that clear the road for private agricultural research. For example, the seed industry in India — which reaches millions of small farmers annually and makes major contributions to yield gains in the country's smallholder-dominated agriculture (Gadwal 2003) — benefits from access to germplasm and breeding lines developed by the public sector. But public agricultural research has lost some of its dominance, luster and dynamic edge. Global public agricultural research spending is down when expressed as a share of agricultural GDP, whereas private spending is up, having grown significantly in the last two to three decades. Creative complementarities and cooperation between the public and the private sector are needed to develop and deliver solutions to large numbers of small farmers. This paper looks at how this can be done.

Impact of private agricultural research

The impact of private agricultural research is less well documented than that of public R&D, and the literature that exists does not have much to say about impacts by farm size. The literature has been reviewed by Pray *et al.* (2007), and it is from this source that this section borrows.

Private R&D fosters innovation and productivity gains in agriculture in both rich and poor countries. A number of studies attest for example to the positive impact of private agricultural research by Indian seed companies on crop yields and farm profits in that country. Econometric studies cited by Pray *et al.* demonstrate that:

- increases in the use of manufactured agricultural inputs developed and sold by the private sector added to average annual agricultural growth in Asia and Latin America, but not in Africa
- private research had the effect of increasing agricultural output by raising total factor productivity when the *quality* of inputs improved such as when breakthrough chemicals and varieties of seed or machinery were developed and diffused.

Assessments of total factor productivity in Indian agriculture that looked at the relative contributions of public and private agricultural research found positive private contributions, but they were smaller than those derived from public R&D.

Studies that examined the impact of private research on productivity changes in particular commodities, especially hybrid maize and poultry, found significant effects on maize yield from research conducted by multinational seed companies and from seed imports. Pray *et al.* note that hybrid seed technology can be transferred directly among temperate countries through seed imports, while adaptive research is required to move technology from temperate to tropical regions. The authors report that private pearl millet and sorghum breeding for the semi-arid tropics made important contributions to farmers' income and welfare in India by increasing yields by means of hybrids that were both high-yielding and resistant to diseases to which public hybrids were susceptible.

Micro-level studies of the impact of private research show similarly strong effects. The CIMMYT[1] impact study of modern maize varieties estimated that by 2000, maize breeding by international, national and private-sector researchers collectively had added about 1 t ha^{-1}, on average, to the 58.8 million ha in developing countries where modern maize varieties had been adopted (Morris 2002, cited from Pray *et al.*).

Private research is undertaken by domestic and multinational companies. The relative effects of each on yields, farm profits and agricultural growth are difficult to disentangle because of the presence of spillovers of private research from

[1] CIMMYT: the Spanish acronym of the International Maize and Wheat Improvement Centre.

rich to poor countries, such as when multinational companies engage in cross-border technology partnerships.

The impact of private agricultural research is easier to demonstrate for certain regions and products than for others. It has visible impact in Latin America, South Africa, Eastern Europe and Asia. In Asia private R&D benefits small farmers almost by definition, because there are few farms there that are not small. There is less impact in Sub-Saharan Africa so far because economic conditions there have long been relatively depressed, seed markets barely exist (see below), and there is a relative disincentive to private research that stems from the region's large number of different crops each with relatively small markets.

Private-sector innovations are dominant in some important product categories: agricultural chemicals, seed treatment, plant growth regulation, fertiliser, machinery, many hybrid varieties and genetically engineered crops. Therefore, where products from these categories are sold and used, impacts of private R&D come into view. In China, genetically modified crops and a significant share of hybrid seeds for key crops are developed by the public sector, but partnerships with private firms are growing. The adoption of products from these categories differs widely across countries and world regions; the reader is referred to Pray *et al.* for data. An aspect that the products have in common, except for some types of mechanisation, is their scale-neutrality and thus their applicability irrespective of farm size, at least in principle.

What then are the factors limiting adoption? 'Farm capability', a concept introduced in the next section, is one such factor. Others include:

- the absence of extension services
- the absence of remunerative links to markets
- the absence of technology that works, either because the research to develop the technology has not been done or because the regulatory framework in the country precludes farmers from accessing it.

The price of purchased inputs, and considerations such as patents, hybrids, oligopolistic conditions in the international crop science industry, and whether or not 'biotechnology' is involved have little or no bearing:

- The price of seed — and crop protection products for that matter — 'is not considered a constraint in usage by the farmers, if the seed (or product) ensures higher return through higher productivity and other value added traits' (Gadwal 2003). This is the inescapable conclusion from data on the growth of the Indian seed market between 1990–1991 and 1998–1999 that show steady increases in (i) area planted to bought seed — including open pollinated varieties — and (ii) proprietary hybrids at the expense of public hybrids even as the average price of proprietary hybrids rose.
- Plant breeders' rights and patents on mechanical, chemical and biological products and processes are a means of promoting and protecting investment in R&D and innovation. Rather than making small farmers in developing countries dependent on expensive inputs, as some tend to argue, these tools of intellectual property lead to the development of technology that would otherwise not become available and that farmers can choose to use or not to use. Hybrid varieties — which provide appropriability without patents — are sought out by farmers because of the yield advantages and other traits that they convey.
- Does industrial concentration or for some reason the evolution of science and 'agricultural biotechnology' create conditions that hinder the adoption of technology by small farmers? Hardly. Some level of concentration is a reality in many economic sectors for many reasons nowadays. It does not mean that there is not competition or that innovation is neglected, as a glance at the information and communications technology sector, automobiles, pharmaceuticals and other industries reveals. The literature on the distribution of benefits from improved varieties — both conventional hybrids and transgenics — among farmers and seed companies dispels the myth of monopoly profits accruing to the industry. Pray *et al.* cite the case of hybrid sorghum in one period in India where seed companies captured less than one-fifth of total benefits, while more than four-fifths went to farmers. Gouse *et al.* (2004) found that during the 2000–2001 cropping season in South Africa, 33% of the benefits from introducing Bt

cotton went to the seed company and its distributors and 67% to domestic farmers.

- As to 'biotechnology' in its various dimensions, including genetic modification, this is a blessing, not a curse — for farmers and farm profitability, consumers and the environment. Agricultural biotechnology helps improve crop plants by providing built-in protection against diseases and insects, and by conveying herbicide tolerance. This creates opportunities to produce more food in sustainable ways.

Pray *et al.* note that the overall importance of private agricultural research to agricultural development has been increasing over time. They also note that private agricultural research is uneven in that it favors certain types of technologies and inputs. (Actually, it is not different from public agricultural research in this respect.) The footprint of private agricultural research in Sub-Saharan Africa is weak. Important questions are what public policy can do to stimulate private research in the full range of challenges that demand solutions, and how private and public research capability can be pooled for the benefit of small farmers. These are addressed below.

The small farm challenge

Census data indicate that there are about 450 million small farms with up to 2 ha of land in non-OECD countries today, mostly in China, the Indian sub-continent and Africa. Assuming an average farm household size of five, the corresponding agricultural population is about 2.3 billion people, a third of mankind. Not surprisingly, the farms operate under a wide range of natural and man-made opportunities and limitations. At the lower end of the spectrum, farms are not viable as economic units in average years. At the upper end, farmers have access to productivity-enhancing technology and are commercial, buying inputs such as seed and fertiliser and selling produce. Agro-dealers (and thus the private sector) are a key source of technology and externally supplied agronomic knowledge and expertise for this group. If one assumes for the sake of an indicative calculation that 40% of the total number of small farms (450 million) run commercial operations — not an implausible figure — one gets a universe of some 270 million small farms in developing and emerging market countries that are 'pre-commercial', practicing what some call 'subsistence farming', a potentially misleading term, among other reasons because it suggests 'autarchy' at the family or community level when in reality nobody can live without money and trade. The yields and profitability of these farms are low, and emigration out of agriculture may be the best option to the extent that there are off-farm jobs domestically or abroad to which farmers in this category can aspire. However, off-farm employment is scarce. The reshaping of economic geography, a process that is massively underway these days, takes time, and farming, therefore, remains the default form of employment for many 'pre-commercial' farmers in the short and medium run.

The private and social pay-off for improving productivity, sustainability and profitability through links to markets of 'pre-commercial' farming is high in this situation. How to get there on the required scale is the break-through question that exercises the professional community that is active in this field. Two phenomena bode well: technology (in the broadest sense of the term) is advancing in leaps and bounds, and markets for agricultural commodities — including high-value products for human consumption such as vegetables and fruit — are growing as never before because of rapid income and continued population growth. The opportunity for transformational change in small-scale farming is there.

Smallness is not an economic condemnation. Small farms can be viable, and many that are not could be with the help of technology and links to markets. Michael Lipton has demonstrated that there is an inverse relationship between farm size and land productivity in labour-abundant developing countries across most conceivable conditions: 'small farms produce more, per hectare per year, than large farms' (Lipton 2009).

As small farmers apply family and community labour that is cheap in relation to capital in developing countries, they face low transaction costs per unit of output associated with labour, the main contributor to output other than land. So investing in small farms by developing technology and making it accessible to them is not 'backward' or a 'lost cause from the outset' as some might have it: it can be a winning proposition, quite apart from being necessary and irreplaceable as a route to food security and poverty reduction in countries

where the rural population is large and most farms are small, as in all of Asia and much of Africa. Paths to food security and poverty reduction that are based on the intensification of smallholder agriculture on a large scale will remain relevant for several decades to come — until spatial demographic realities change and the urban and rural non-agricultural economy lastingly absorbs a large share of agricultural labour.

Agricultural intensification requires technology and also services by which inputs are delivered and farmers can be linked to markets. Exhibit 1 lists some of the products and practices that this entails: varieties, chemicals, mechanical tools, fertiliser and agronomic practices, to mention but some of the components of 'technology'. Key services include seed and other input systems, agricultural extension, connectivity, market and weather data, financial services such as credit and agricultural insurance, infrastructure, 'conducive' agricultural and trade policies, and market access for the farmer.

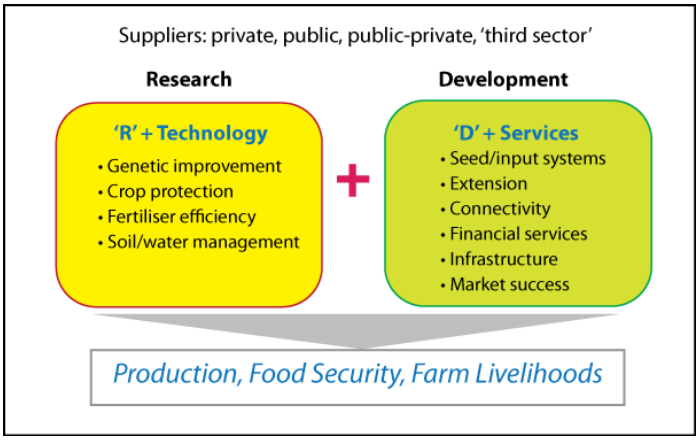


Exhibit 1. Technology and services
Syngenta Foundation for Sustainable Agriculture

Needs for technology and the capacity to productively absorb external inputs vary with the 'capability' of farms. Exhibit 2 suggests a way of thinking about agricultural intensification from 'enhanced basics' at the cash- and endowment-strapped bottom to successively more professional levels of inputs and technology as capability expands. It is an additive progression: basic elements of technology need to be present at each successive step.

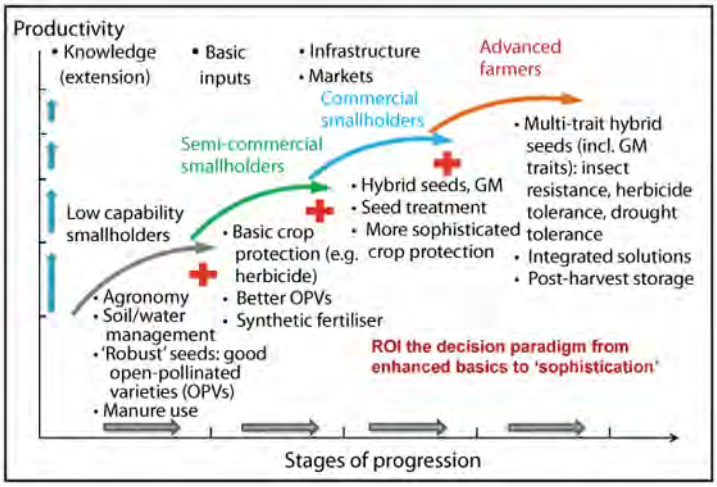


Exhibit 2. Farm capability as an additive progression
(ROI = return on investment) Syngenta Foundation for Sustainable Agriculture

At the low end of the spectrum, improved agronomy (and thus competent extension services, privately or publicly supplied, or offered through mixed partnerships), seeds (typically of the farmer-saved kind), and basic soil nutrients are the priority. At higher levels, there is scope for additions to the basics that farmers can afford if there are links to markets. These additions include hybrids, possibly transgenic traits and stacks, modern crop protection, crop enhancement chemistry, nutritional content enhancement through biofortification, precision agriculture and so on, all ideally combined with low-tillage farming and other methods to preserve water and take care of soils. 'Return on investment' ('ROI' in Exhibit 2) is the decision paradigm.

Note at the same time that there is not only movement to the right in the progression, but also movement up. Farmers can improve farming within their capability ('horses for courses') as the widespread adoption of Bt cotton by smallholders in India suggests. Even at the simplest and essentially 'organic' level of farming, improvements in land management and yield can be achieved.

The 'natural' supporting actors in this model differ depending on the point in the progression (cf. Exhibit 3). Not-for-profit actors — foundations and NGOs professionally specialised in agriculture, and the public sector — are vital at the lower end. For-profit sector companies (and their distributors) selling fertilisers, machinery, agro-chemicals and seeds can be expected to

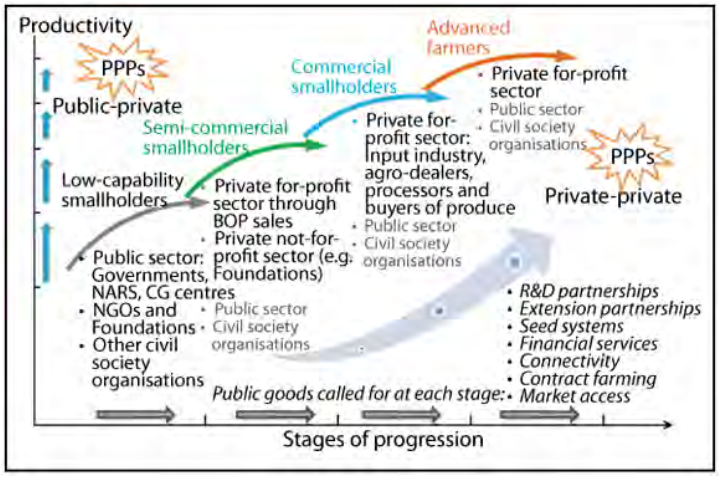


Exhibit 3. Stakeholders and the additive progression
Syngenta Foundation for Sustainable Agriculture

come in as capability expands. This can create movement to the right or vertically as a result of good agricultural extension or in response to relevant technologies that spread by themselves as in the case of Bt cotton in some countries. Farmers, even very modest ones, will buy inputs if they detect an opportunity to realise returns.

The R&D challenge in smallholder agriculture is to develop the right kinds of products for different farm capabilities and agro-ecological conditions and then take them to market and the farmer. This may sound easy, but it is not. Partnerships can help in two respects: to bring out synergy between private and public entities in agricultural research and to develop — or 'kick-start' — input markets where they do not exist.

Business partnerships in agricultural research

Agricultural technology is in essence about realising yield potential. The seed that the farmer plants holds yield potential that must be protected in the face of risk. This is achieved with the help of inputs and management that include traits (derived conventionally or through genetic modification), seed treatment, sprays, fertiliser and 'agronomy', where particular attention is paid to water and nutrient management and postharvest technology. Ultimately, too, a healthy farmer is a pre-requisite for effective risk management and the achievement of yield potential.

How to enhance the yield potential that is embodied in the seed? Molecular breeding building on the genomics revolution of the past decade is the key. Transgenic approaches can also offer some specific scope.

It turns out that molecular breeding presents 'natural' opportunities for partnerships between the public and the private sector such as centres of the Consultative Group for International Agricultural Research (CGIAR) and national programs, on the one hand, and crop science companies on the other. This is so because of the distribution of comparative advantages in phenotyping and genotyping, both of which are needed to develop varieties and traits that are of interest to farmers.

The public sector, with its germplasm resources and knowledge derived from *in situ* field trials, has particular strengths in phenotyping and breeding, whereas the private sector, with its high-throughput genomic and bioinformatics capabilities, is well resourced to contribute knowledge and capability on gene sequencing and genotyping. Opportunities and needs for partnerships arise when private companies and public organisations lack the resources or incentives to fully develop products or exploit their assets independently — an almost everyday occurrence where research for 'pre-commercial' agriculture is concerned.

Unfortunately, the types of partnerships that are desirable — with symmetry as far as the distribution of burdens and benefits is concerned and clarity as to the objectives, the business plan, the protection of (and agreement on how to exploit) intellectual property, and accountability for deliverables — are not necessarily easy to bring about. Deals must be negotiated, and there is little to go by in the form of precedent and guidance. Public–private partnerships in international agricultural research are slowly growing in number, but each deal is generic — which does not mean it cannot be part of a publicly announced, consistent strategy. The examples in Table 1 are vital aspects of plans by individual international agricultural research centers to gain relevance through products using advanced genomics, molecular biology and breeding methods.

Table 1. Recent examples of public–private partnerships in international agricultural research.
Source: Private sector and AATF websites Syngenta Foundation for Sustainable Agriculture

Partner / partnership	Date announced	Partners	Objectives
Rice science exchange and collaboration programme	December 2009	Bayer CropScience, International Rice Research Centre (IRRI)	To strengthen rice productivity by utilising rice genetic diversity, development of diagnostic tools for seed-borne bacterial leaf blight, monitoring greenhouse gas emissions from growing systems, and capacity building for young rice scientists.
Wheat rust resistance research partnership	August 2009	Syngenta, International Maize and Wheat Improvement Centre (CIMMYT)	To rapidly identify and map genetic markers to support wheat resistance breeding against Ug99 stem rust (*Puccinia graminis*). This fungus is causing devastating crop losses and spreading across Africa, Asia and the Middle East.
Boosting rice yields — science exchange program	March 2009	DuPont, International Rice Research Centre (IRRI)	To strengthen and accelerate breeding efforts and commercialisation of higher-yielding hybrids with added resistance to brown plant hopper. To boost the quality and diversity of hybrid rice in Asia. Doctorate scholarship programme for rice scientists for Asia.
Water-Efficient Maize for Africa (WEMA) (A multilateral consortium led by AATF)	March 2008	Monsanto, International Maize and Wheat Improvement Centre (CIMMYT); African Agricultural Technology Foundation (AATF); National Agricultural Research Systems (NARS) in five African countries	To use marker-assisted breeding and biotechnology to develop African maize varieties with the long-term goal of making drought-tolerant maize available royalty-free to African small-scale farmers.

As an example, the Syngenta Foundation for Sustainable Agriculture brokered an agreement between Syngenta (the Corporation) and CIMMYT in 2009 to cooperate on breeding for resistance to Ug99, the new, virulent strain of stem rust (a fungal disease) that threatens the global wheat harvest and requires stepped-up research to find sources of resistance and to breed varieties that can cope.

The two-year project seeks to rapidly identify and map genetic markers for use in wheat resistance breeding. Funded by the Foundation, the project combines Syngenta's genetic profiling expertise with the strengths of CIMMYT's extensive field research to develop a genetic map of wheat stem rust resistance. This will culminate in the development of wheat varieties that have better tolerance to the disease.

The results from this project will contribute directly to the global effort to combat stem rust, which is coordinated by the Borlaug Global Rust Initiative. The marker data arising from the research will be published. Pre-breeding information developed by the project will thus be in the public domain for others to use without restriction — a standard to which public–private partnerships in international agricultural research should rise. In turn, the breeding products that are expected to be developed by CIMMYT and Syngenta, respectively, will be marketed by each in its geographies and markets.

A CGIAR *Workshop on Public Private Partnerships and Associated Needs for Product Stewardship and Liability* was hosted by the Syngenta Foundation in November 2009. The workshop concluded that 'PPPs (public private partnerships) should be seen as a valuable and effective vehicle … to capitalise on the complementarities that exist between the CGIAR and the private sector's R&D value-creation process'.[2]

[2] http://www.cgiar.org/PSC/index.html

Participants noted the need to bring R&D closer together with product dissemination and deployment to generate impact where it matters, that is in farmers' fields. They recognised strengths of the private sector that go beyond breeding, transgenics and pre-breeding — for example, in project management and how to organise a research process with a development mindset to bring products to the market and to farmers in good time. Likewise, they recognised the private sector's assets of know-how and expertise in stewardship management. High quality stewardship management capacity is a pre-condition for the introduction of transgenic events anywhere. The Syngenta Foundation is funding a project in biosafety and stewardship management in Africa and is partnering with the Forum of Agricultural Research for Africa (FARA) to catalyse sharing of best practice in stewardship between private- and public-sector R&D and seed communities.

All told, a new reality was recognised: given the lay of incentives and comparative advantage, partnerships (or perhaps a form of joint ventures) between the public and the private for-profit and not-for-profit sectors are needed to reach large numbers of small farmers. The list of implementation issues is non-trivial, however, and must be dealt with. It includes the need for agreement on the sharing of germplasm, open access to data, implementable approaches to market segmentation, arrangements to deal with stewardship and liability in the case of transgenic crops, market analysis, and performing routes to market and the farmer.

Business partnerships to kick-start input markets

Routes to market and the farmer are as important as advanced chemistry and genomics, if the objective is to achieve change on the ground. Markets are needed to help the millions of small farmers that must be reached in the effort to bring technology to every acre farmed. Some rural markets clearly work, reaching customers on a massive scale: think of soap, certain drinks and mobile phones. For agricultural input products and services this is not the case, at least not to the same extent, because of demand- and supply-side constraints that need to be addressed.

On the demand side, for farmers to buy inputs and services they must have access to markets for their products (a vital topic not specifically discussed in this paper because of space limitations) or a source of income such as cash entitlements or off-farm employment. Well administered and effective intermediate solutions — typically partnership-based, such as when governments or NGOs buy and distribute seed and fertiliser at subsidised rates — can help ease the demand constraint in subsequent years if they engender income growth. The question is whether and to what extent they do.

On the supply side, the first aspect to note is that selling to different farm capabilities at the bottom of the pyramid is well-known as a method in the input and crop-science industry and practised by agro-dealers all over the developing world. But in agriculture special considerations apply: the first is the fact that for best results and safe and effective use, inputs must be marketed along with knowledge, the delivery of which must be provided for in farmer-interactive ways that foster learning. This can complicate the task. The second consideration refers to regulation. Inputs such as seed and crop protection products are regulated, and regulation, if it is not well designed and properly administered, can have the unintended effect of withholding safe and needed products from the market.

Thus, for seeds, unrealistic quality standards are sometimes encountered that inhibit the emergence of a seed industry. Where national markets are small, as in Africa, the lack of harmonisation of seed laws across countries (such as related to varietal release, phyto-sanitary standards and plant variety protection) hampers the emergence of seed companies and markets by inhibiting cross-border trade.

In crop protection, farmers need access to the most effective agents with the greatest operator and environmental safety profiles, rather than the old and outmoded generic technology that one frequently encounters in developing countries and emerging markets. Regulatory systems often fail to provide for this. Cross-border regulatory harmonisation, too, would help because of the high cost of registering new products and the resulting disincentive to take them to small markets.

So for input markets to begin to function, and for products to become available to farmers, certain conditions need to be fulfilled, particularly as related to regulation and stewardship capacity as discussed in the previous section. Partnerships can then play productive roles, as shown forthwith with reference to seeds and fertiliser. Exhibit 4 on area shares of maize seed types displays the

position of selected countries in the landscape of proprietary, publicly supplied and unimproved farmer-saved seed. Not surprisingly, the private sector's presence measured in area shares is much higher in the selected Asian cases with their relatively well-developed seed markets and seed distribution systems than in Africa, except for South Africa.

Seed markets and seed systems are in rudimentary stages of development in much of Africa. It can take years for improved varieties to find their way to farmers' fields — some never make it — for reasons having to do with four sets of challenges:

- the e*stablishment of seed companies* in what are uncertain, high-cost, and over- and ill-regulated environments
- the *production of seed*, which is plagued by the lack of access to germplasm and credit, among other factors
- the *marketing of seed*, where poor infrastructure is a constraint
- the *demand for seed* at the farm level, which is low because of the absence of supporting services and problems with grain marketing on the output side (Langyintuo *et al.* 2008).

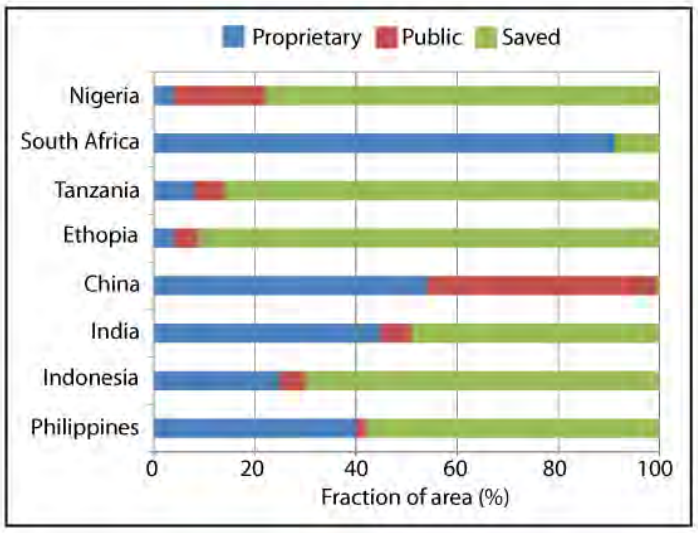


Exhibit 4. Area share of maize seed types, selected countries
Source: Global Seed Market Database, 2009.
Syngenta Foundation for Sustainable Agriculture

In India, the seed business took off decades ago with the advent of private seed companies that operated in close partnership with the public sector and benefitted from public germplasm, pragmatic regulation with the 1964 Seeds Act and the New Seed Policy of 1986 as milestones, and support from the Rockefeller Foundation in the early days and to this day from the national agricultural research system and the CGIAR.

Partnerships of this kind are needed in Africa to give rise to an entrepreneurial class in the seed sector — managers and business owners who understand plant breeding and the intricacies of seed production, the challenges of seed promotion, marketing and pricing, and the need for seed companies to provide advice linked to their products on all aspects of cultivation: land selection and preparation, fertiliser application, irrigation and moisture management, pest, weed and disease control, and harvesting and postharvest technology.

Fortunately, a number of partnerships and efforts are underway at the national and sub-regional level in Africa to drive seed policy reform, link public-sector breeding efforts and emerging private actors, create conditions for commercial investments in R&D, and establish seed consortia to bring together different types of implementing partners to address seed sector development in a coordinated way. Vitally important 'work in progress', clearly, where governments, donors, the Alliance for a Green Revolution for Africa (AGRA) and programs by some of the centres of the CGIAR are working in tandem with emerging local firms that themselves are getting organised in national seed trade associations. An African Seed Trade Association was formed in 2000 to represent the African private seed sector to promote production, marketing and the use of improved seed.

Public–private partnerships are also at work in fertiliser distribution. Under the Rwandan Government's Crop Intensification Program, for example, an apparently effective public–private partnership to develop a market for fertiliser and distribute fertiliser to small farmers has been underway since the 2007 main cropping season. The partnership takes the form of an auction for fertiliser: the government imports fertiliser and auctions it off to private distributors who then transport and sell it to communities and farmers at the local level, sometimes in package deals with seed. The effects on the quantities of fertiliser

moved and maize yields have been significant, aided by adequate rains, with maize yields rising, on average, from 0.7 t ha^{-1} in 2007 to 1.1 t ha^{-1} in 2008 and 1.7 t ha^{-1} in 2009 according to crop assessment data of the Ministry of Agriculture.

Versions of Rwanda's model of public–private partnership for agricultural inputs are in effect in many African countries today; Kenya's National Accelerated Agricultural Inputs Program is an example with a unique feature that links farmers to credit from Equity Bank. The challenges of design and implementation of these programs, which must have an exit strategy, are significant, of course, but so are the benefits, potentially, in the form of improved productivity of small farms, farm income, and as a contribution to the development of input markets. This contribution can be expected to be the more 'productive', the better organised and stronger markets are on the output side. The World Food Programme's local food procurement program 'Purchase for Progress' can play a role in this respect by helping to develop secure markets for farmers' harvests.

Conclusion

The answer to the question posed in the title of this paper is 'yes, private-sector R&D can reach 'pre-commercial' small farmers at low levels of capability, provided the public and the private for-profit and not-for-profit sector work in partnership along the full value chain from 'R' (i.e., research) to 'D' (i.e., product development and introduction), supported by functioning markets on the output side'. The generic functions that must be combined include helpful policies and regulation from the public sector; products and investments to develop the market from the business sector; and a role of 'tipping the scales' for foundations and not-for-profits.

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Reassessing Public–Private Roles in Agricultural R&D for Economic Development

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A key to securing global food security, conserving biodiversity and achieving climate change objectives as well as other concerns of international importance will be to sustain if not enhance productivity gains in agriculture. However, there are indications that productivity growth is slowing in staple food and feed crops around the world, and that the pace of investment in agricultural R&D — a primary source of the innovations that spur productivity — has slowed as well. The nature and magnitude of these shifts are spelled out in this paper. Reinvigorating agricultural research will be pivotal to turning these productivity trends around. The public sector has a key role to play, but the private sector will also contribute. However, the actions of the for-profit private sector are shaped by commercial realities that will limit their role in many, but by no means all, developing-country markets for many years to come. Thus a complementary public–private strategy will be the key to success. The private-sector roles in agricultural research are briefly described, along with the underlying economic factors at play, as a basis for informing the important policy and institutional choices and changes that will be required if the promise of increased agricultural productivity gains is to be realised in the decades ahead. The stakes are high, not least because decisions and actions taken (or not taken) now will have consequences for many years to come.

This is an abridged and reworked version of a 2009 report prepared for the Center for Strategic and International Studies (CSIS), Washington DC, by P.G. Pardey and J.M. Alston and titled *U.S. Agricultural Research in a Global Food Security Setting*.

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Introduction

In the past half-century, agricultural science achieved a great deal. Since 1960, the world's population has more than doubled, from 3.1 billion to 6.7 billion, and real per capita income has nearly tripled. Over the same period, total production of cereals grew faster than population, from 877 million metric tons in 1961 to over 2351 million metric tons in 2007, and this increase was largely owing to unprecedented increases in crop yields.[3] The fact that the Malthusian nightmare has not been realised over the past 50 years is attributable in large part to improvements in agricultural productivity achieved through technological change enabled by investments in agricultural R&D.

Notwithstanding these remarkable achievements, agricultural R&D is now at a crossroads. The

[3] Obtained from FAO (2009)

close of the 20th century marked changes in policy contexts, fundamental shifts in the scientific basis for agricultural R&D, and shifting funding patterns for agricultural R&D in developed countries. Even though rates of return to agricultural research are demonstrably very high, we have seen a slowdown in spending growth and a diversion of funds away from farm productivity enhancement, at least in the United States and, it appears, in other rich countries as well. Together these trends spell a slowdown in farm productivity growth at a time when the market has, perhaps, begun to signal the beginning of the end of a half-century and more of global agricultural abundance. It is a crucial time for rethinking national policies and revitalising multinational approaches for financing and conducting agricultural research.

Following a brief description of the links between agricultural R&D, productivity growth and food security outcomes, we review the patterns of agricultural productivity growth. The evolving institutional and investment realities confronting agricultural R&D are presented, including developments in the public and private sectors. Agricultural R&D has some distinctive attributes that are critical to bear in mind, and especially so when thinking about the food security and general economic implications of that research. These dimensions are described and need to be borne in mind when taking the practical policy actions that will be required to revitalise agricultural R&D to meet the global food (and climate change and other) challenges looming in the decades ahead.

R&D – productivity – food security linkages

Growth in demand for agricultural commodities largely stems from growth in demand for food, which is driven by growth in population and per capita incomes (especially the economic growth of the fast-growing economies of Asia), coupled with new demands for biofuels. Growth in supply of agricultural commodities is primarily driven by growth in productivity, especially as growth in the availability of land and water resources for agriculture has become more constrained. Productivity improvements in agriculture are strongly associated with lagged R&D spending, as revealed in a large compilation of country-specific studies reported in Alston *et al.* (2000). Thus, the rate of growth of investments in agricultural R&D and the uses to which those research dollars are put will be a pivotal determinant of long-term growth in the supply, availability and price of food over the coming decades.

Productivity growth has been the main driver, and has contributed enormously to growth in supply of food and fiber. These productivity gains can be measured in various ways. Conventional measures of productivity measure the quantity of output relative to the quantity of inputs. If output grows at the same pace as inputs, then productivity is unchanged: if the rate of growth in output exceeds the rate of growth in the use of inputs, then productivity growth is positive. Partial-factor productivity measures express output relative to a particular input (like land or labor).[4] Multifactor productivity measures express output relative to a more inclusive metric of all *measurable* inputs (including land, labor and capital, as well as energy, chemicals and other purchased inputs). Measures of agricultural productivity growth for the United States (the world's largest producer of corn and soybeans, and third-largest producer of wheat) — be they crop yields, other partial-factor productivity measures (for example, measures of land and labor productivity), or indexes of multifactor productivity — show generally consistent patterns in terms of secular shifts, including indications of a recent slowdown in growth (Alston *et al.* 2009a,b).

Drawing conclusions on the Australian evidence on the pace of agricultural productivity growth is confounded by differences among different measures in industry coverage (e.g., the broadacre agriculture — i.e., livestock and cropping — output orientation of the ABARE measure versus the more comprehensive agricultural, forestry and fisheries coverage of the ABS measure), differences in the measure of output itself (e.g., the gross-value measure of the ABARE metric versus the value-added measure reported by ABS), and, perhaps, as yet unreconciled differences in the measures of aggregate input used to form the respective multifactor productivity estimates.

Substantial year-to-year (weather-induced) fluctuations in output and hence productivity, with a string of particularly bad seasons in more recent years, also complicates efforts to disentangle temporary fluctuations from sustained shifts in these trends. In Mullen's (2010) recent assessment of this evidence, he concludes that:

[4] Crop yields represent a particular partial productivity measure wherein the physical output for a particular crop is expressed relative to land input.

According to the ABS valued added measure, productivity growth in the agriculture, fisheries, and forestry sector has remained strong despite a weakening in the rest of the economy, growing at the rate of 2.5% per year in the ten years to 2007. However, ABARE estimates for broadacre agriculture suggest that productivity growth slowed in the ten years to 2007.

The final story concerning this Australian evidence is probably yet to be written, but there is certainly cause for concern about the recent pace of productivity growth in the basic food and feed sectors.

Paralleling productivity developments in Australia, the United States and other OECD (Organization for Economic Cooperation and Development) countries, the evidence of a slowdown in crop yields throughout the world is quite pervasive. In more than half of the countries growing each crop, yields for rice, wheat, maize and soybeans grew more slowly during 1990–2007 than during 1961–1990. More critically, the slowdown was more widespread among the most important producers (i.e., the top-ten producing countries worldwide) than among all producing countries.

Like the global crop yield evidence just described, the longer-run rates of growth in land and labor productivity worldwide mask a widespread slowdown in the rate of growth of both productivity measures in 1990–2007 compared with the previous three decades. Among the world's top-20 producers (according to their 2005 value of agricultural output), compared with 1961–1990, land and labor productivity growth slowed considerably during 1990–2007 once the large, and in many respects exceptional, case of China is set aside. Across the rest of the world (i.e., after setting aside the top-20 producing countries), on average, the slowdown was even more pronounced. For this group of countries land productivity grew by 1.74% per year during 1961–1990, but only 0.88% per year thereafter; labor productivity grew by 1.00% per year during 1961–1990, but barely changed over the period since then.

Agricultural R&D investments and institutions

Many factors may have contributed to the slowdown in agricultural productivity growth. Changes in weather or climate, land degradation, shifts of the location of production to less favorable environments, farmer responses to resource scarcity or higher prices of inputs, changes in public institutions, and evolving pests and diseases may all have contributed. Agricultural R&D is an important element of the story, a critical policy instrument that governments can apply to influence the path of agricultural productivity. Understanding the changing patterns of investment in agricultural R&D in the United States and elsewhere in the world is essential for understanding likely prospects for food security. The lags between investing in agricultural R&D and realising a productivity-enhancing return on that investment are long — a matter of decades not years — which dictates taking a very long-run perspective on R&D spending trends.

Public sector — global trends

Worldwide, public investment in agricultural R&D increased by 35% in inflation-adjusted terms between 1981 and 2000; from an estimated $14.2 billion to $20.3 billion in 2000 international dollars (Fig. 1).[5] It grew faster in developing countries (from $5.9 billion to 10.0 billion, a 53% increase), and the developing world now accounts for about half of global public-sector spending —

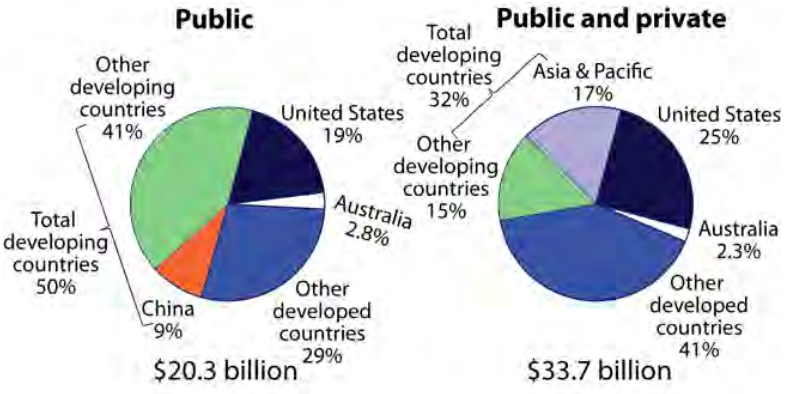

Figure 1. Global agricultural R&D spending, 2000. Sources: Pardey *et al.* (2006b) and Alston *et al.* (2010).
Notes: Expenditures are international dollars (converted with World Bank (2008) purchasing power parities).

[5] Year 2000 is the last year for which internationally comparable data on agricultural R&D investments are presently available.

up from an estimated 41% share in 1980. However, developing countries account for only about one-third of the world's total agricultural R&D spending when private investments are included.

Public spending on agricultural R&D is highly concentrated, with the top five percent of countries in the data set (i.e., 6 countries in a total of 129) accounting for about half of the spending. The United States alone constituted almost 20% of global spending on publicly-performed agricultural research. The Asia and Pacific region has continued to gain ground, accounting for an ever-larger share of the world and developing-country total since 1981 (25.1% of the world total in 2000, up from 15.7% in 1981).

In 2000, just two countries from this region, China and India, accounted for 29.1% of *all* expenditure on public agricultural R&D by developing countries (and more than 14% of public agricultural R&D globally), a substantial increase from their 15.6% combined share in 1981. In stark contrast, sub-Saharan Africa continued to lose ground — its share fell from 17.9% of the total investment in public agricultural R&D by developing countries in 1981 to 11.9% in 2000.

A notable aspect of these trends is the pervasive slowdown in the pace of growth of public agricultural R&D spending, especially among the rich countries. During the 1980s rich-country investments in public agricultural R&D grew by an average of 1.89% per year in inflation-adjusted terms. This slowed to just 0.38% per year growth during the 1990s and that slowdown has persisted during the past decade. Similar to the US trends, spending on agricultural R&D in Australia grew by just 0.81% per year from 1990 to 2007, compared with 4.43% per year from 1950–1953 to 1990 (Fig. 2).

The intensity of agricultural R&D — that is, agricultural R&D spending relative to the economic size of the agricultural sector it serves — is also much lower in developing countries. In 2000, developing countries spent just $0.50 on public agricultural R&D for every $100 of agricultural output, compared with $2.36 for developed countries as a group (in this case, agricultural R&D spending expressed as a percentage of agricultural gross domestic product, AgGDP). The public agricultural R&D intensity in developed countries grew from $1.62 per $100 of output in 1980 to $2.33 per $100 of output in 1991 but has barely risen since. In contrast, the overall agricultural R&D intensity was static in developing countries over the entire period.

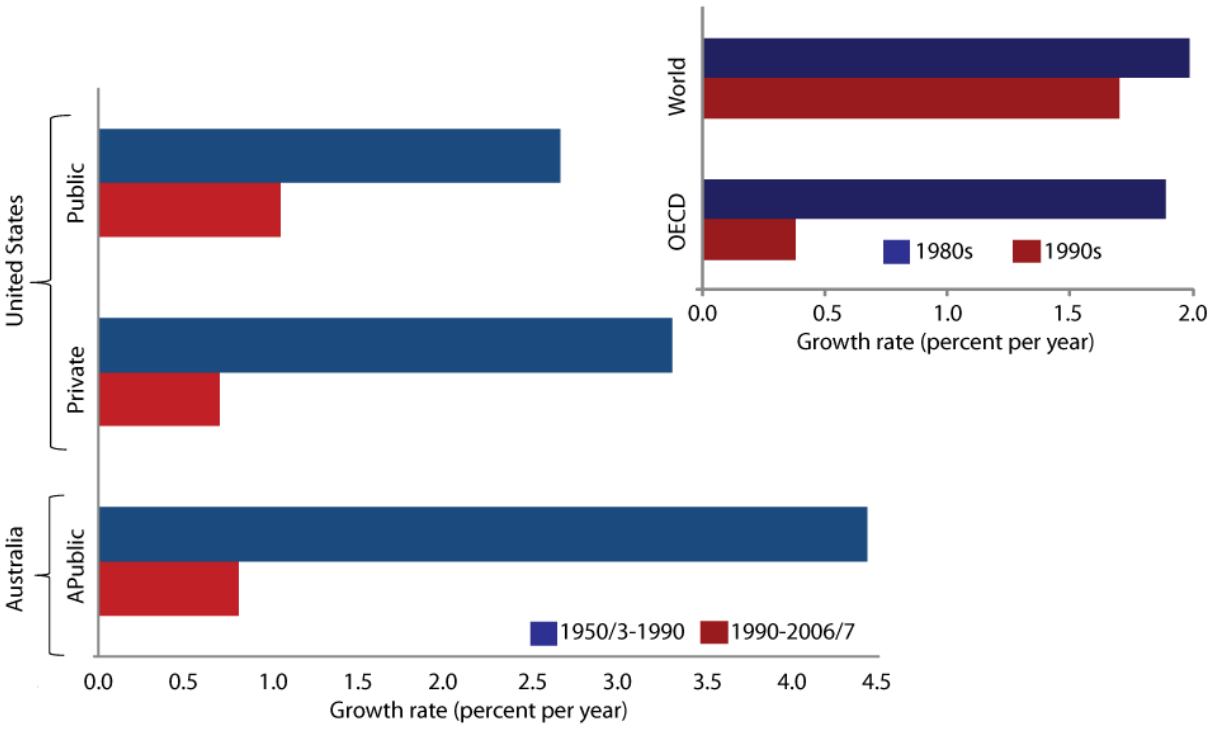

Figure 2. Agricultural R&D spending growth rates. Sources: Pardey *et al.* (2006), Alston *et al.* (2010) and Mullen (2010). Note: US data are for 1950–2006, Australian data are for 1953–2007.

Private sector — global trends

The private sector has continued to emphasise inventions that are amenable to various intellectual property (IP) protection options such as hybrid crops, patents and more recently, plant breeders' rights and other forms of IP protection. The private sector has a large presence in agricultural R&D, but with dramatic differences among countries. In 2000, the global total spending on agricultural R&D (including pre-, on-, and post-farm oriented R&D) was estimated to be $33.7 billion. About 40% was conducted by private firms and the remaining 60% by public agencies.

Notably, 95% of that private R&D was performed in developed counties, where some 55% of total agricultural R&D was private, a sizeable increase from the 44% private share in 1981.

This rich-country trend may well continue if the science of agriculture increasingly looks like the sciences more generally. These increasing private shares reflect increasing industry R&D by the farm-input supply and the food processing sectors. However, around the general trend was much country-specific variation (Fig. 3). Japan conducted a slightly larger share of its agricultural R&D in the private sector than the United States whereas Australia and Canada — both reliant on privately developed, technology-intensive imports of farm machinery, chemicals and other agricultural inputs — had private-sector shares of agricultural R&D spending less than 35% in 2000 (Pardey *et al.* 2006b).

In developing countries, only 6.4% of the agricultural R&D was private, and there were large disparities in the private share among regions of the developing world. In the Asia and Pacific region, around 9% of the agricultural R&D was private, compared with only 1.7% of the R&D throughout sub-Saharan Africa.

Most private agricultural R&D in sub-Saharan Africa was oriented to crop-improvement research, often (but not always) dealing with export crops such as cotton in Zambia and Madagascar and sugarcane in Sudan and Uganda.

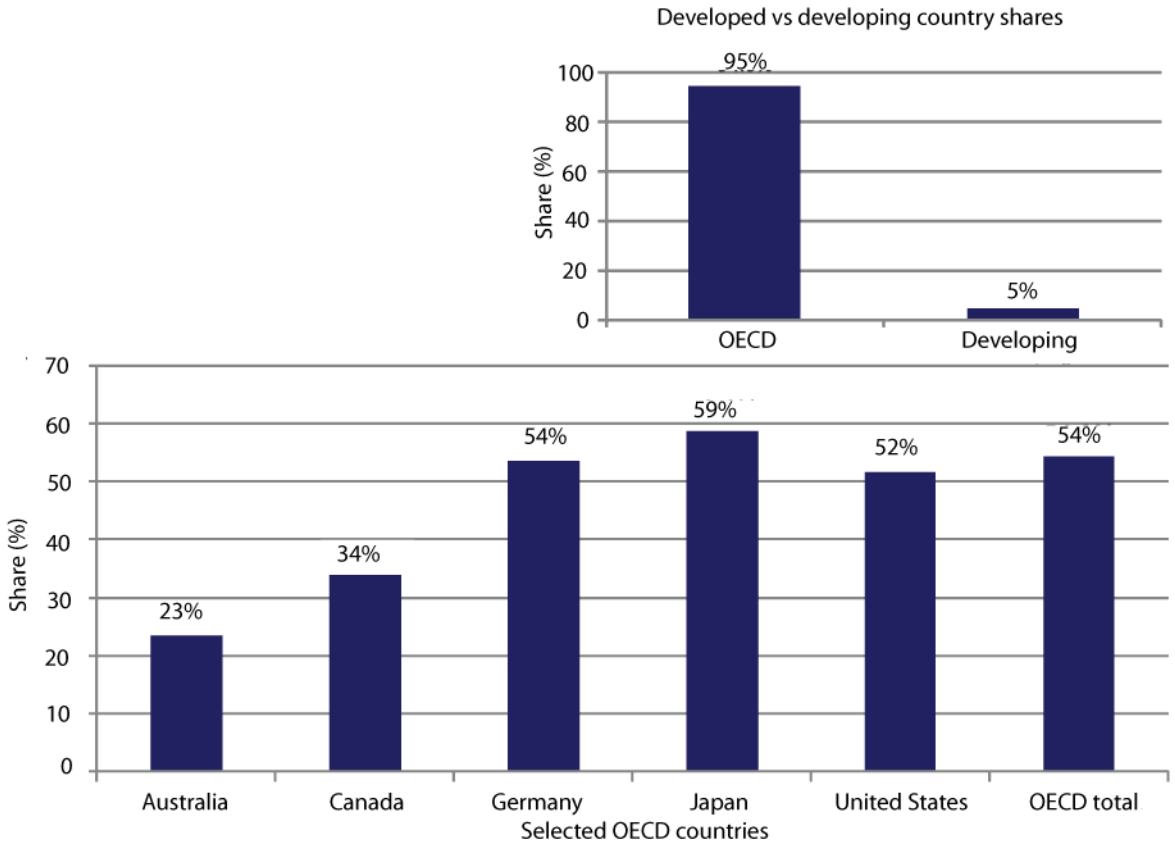

Figure 3. Private shares of agricultural R&D, circa 2000. Sources: Pardey *et al.* (2006).

South Africa carried out around half of the total measured amount of private agricultural R&D performed throughout Sub-Saharan Africa.

The more limited private-sector participation in agricultural research done in or for developing countries stems from several factors, many of which are likely to persist for some time (with some likely exceptions, such as Brazil, China and India). A significant share of food produced in developing countries is consumed within the household where it is produced. Even when commodities enter the marketing chain, in less-developed countries they are less often purchased in highly transformed forms, with food more-often prepared and eaten at home. Consequently, a much smaller share of the food bill in developing counties accrues to post-farm food processing, shipping and merchandising activities; areas where the incentives for private innovation are relatively pronounced.

Likewise, on the supply side, purchased inputs (such as herbicides, insecticides, improved crop varieties or animal breeds, and all sorts of agricultural machinery) constitute a comparatively small share of the total costs of production in many parts of the developing world. While these characteristics of the production and consumption of food, feed and fiber commodities are likely to change as incomes rise and infrastructure improves, the pace of change will be gradual in the poorest areas where (semi-) subsistence farming still predominates. The cost of doing business in places characterised by small and often remote farms subject to poor market access, lack of farm credit and limited communication services also undercuts private participation in these agribusiness sectors, in turn reducing the private incentives to invest in R&D targeted to these markets. Finally, a plethora of regulations, often inefficiently enforced, make it difficult for local and multinational private interests to penetrate agricultural markets with new seed, chemical or other agricultural technologies in substantial parts of the developing world.

The rich-country : poor-country disparity in the intensity of agricultural research noted above is magnified dramatically if private research is also factored in. In 2000, in developing countries as a group the ratio of total agricultural R&D spending to agricultural GDP was 0.54% (i.e., for every $100 of agricultural GDP, just 54 cents was spent on agricultural R&D). In developed countries the comparable intensity ratio was 5.28% (i.e., $5.28 per $100), almost ten times greater (Fig. 4).

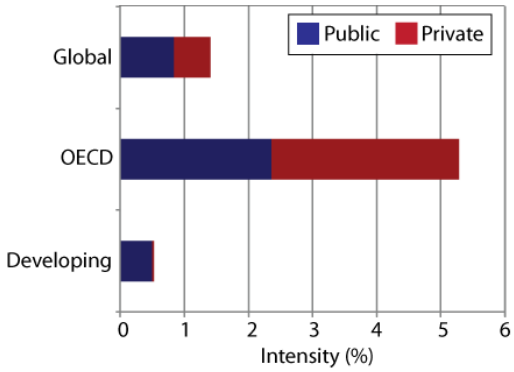

Figure 4. Intensity of agricultural R&D spending, 2000. Sources: Pardey *et al.* (2006). Note: Research intensity represents agricultural research expenditures divided by corresponding agricultural gross domestic product (GDP).

Rich versus poor countries — a growing scientific and knowledge divide

Collectively the Australian and global agricultural R&D trends point to two disturbing developments: first a pervasive slowdown in the rate of growth of agricultural R&D spending, and second, a growing rich-country : poor-country divide in the conduct of and thus the innovations emanating from (agricultural) R&D. To the extent the R&D spending slowdown is a widespread phenomenon, it will serve to slow or reverse the long-run decline in staple food and feed prices and add to the dismal tally of hungry and malnourished people worldwide. To the extent the food and agricultural attributes of agricultural R&D conducted in rich countries increasingly targets income-elastic attributes, the technological divide between rich- and poor-country agriculture will widen. Only a few developing countries (including Brazil, China and India) show signs of closing in on the larger amounts and higher intensity of investment in agricultural R&D typically found in the rich countries. Meanwhile, large numbers of developing countries are either stalling or slipping in terms of the amount spent on agricultural R&D, the intensity of investment, or both.

A comparison of agricultural R&D realities in Sub-Saharan Africa (a region consisting of 42 contiguous countries plus 6 island nations), India (a nation of 28 states and 7 union territories, 21 and 5 of them contiguous, respectively), and the United States (a nation of 50 states, 48 of them contiguous) makes more concrete the nature of

this technological divide. The arable agricultural areas in these three parts of the world are similar, but Indian and African agriculture uses far fewer hectares per worker than in the United States. Moreover, land and labor are still dominant components of the cost of production in Sub-Saharan Africa and India, whereas in the United States the combined cost share of these two inputs fell considerably during the past 50 years at least. Purchased inputs now constitute 38% of the total cost of production in US agriculture, compared with 23% in 1949.

Not only is the structure of agriculture dramatically different, the structure of agricultural R&D is also markedly distinct. For most measures, the starkest contrast is between the United States and Sub-Saharan Africa, with India usually somewhere in between. Africa has almost 30% more public agricultural researchers than the United States and 50% more than India, but the training of these researchers continues to lag well behind those in the United States (and well behind those researchers working elsewhere in the developing world). About 25% of research full-time equivalents (FTEs) in Sub-Saharan Africa have PhDs, compared with 100% in the United States and 63% in India. Accounting for the 'quality' of the researchers, in terms of their educational status, the quantity of effective scientific labor going into agricultural R&D in Africa is significantly less than the quantity in India and the United States.

African public agricultural research agencies are heavily skewed to the small end of the size distribution, with three-quarters of these agencies employing fewer than 20 researchers, whereas one-third of the public agencies in India and almost all the public agencies in the United States employ more than 100 researchers. The small size of many research agencies in India and particularly in sub-Saharan Africa makes it difficult to exploit the economies of scale that characterise the production of knowledge. Moreover, the lion's share of public research in the United States is now performed by universities, while the average university share is less than 20% in sub-Saharan Africa and about 45% in India.[6] Crucially, real spending per researcher in the United States is more than double its counterpart in India and more than four times its counterpart in sub-Saharan Africa; and the gap is growing. The long-run trend continues to be an increase in spending per scientist in the United States while inflation-adjusted spending in sub-Saharan Africa has shrunk to less than half what it was in 1981.

These measures suggest the immensity of the challenge of playing catch-up in countries like India, and the seeming impossibility of catching up in sub-Saharan Africa.

The measures also underscore the need to transmit knowledge across borders and continents and to raise current amounts of funding for agricultural R&D while also developing the policy and infrastructure needed to accelerate the rate of knowledge creation and accumulation in the developing world over the long haul. Developing local capacity to carry forward findings will yield a double dividend: increasing local innovative capacities while also enhancing the ability of local research agencies to tap discoveries made elsewhere. It is also essential to increase complementary investments in primary, secondary and higher education if the generation and accumulation of knowledge is to gain the momentum required to put economies on a path to lift people out of poverty.

In addition to these broad trends, other aspects of agricultural R&D funding that have important practical consequences are also of concern. For example, variability in R&D funding continues to be problematic for many developing-country research agencies. This is especially troubling for agricultural R&D given the long gestation period for new crop varieties and livestock breeds, and the desirability of long-term employment assurances for scientists and other staff (Pardey *et al.* 2006a). Variability encourages an over-emphasis on short-term projects or on projects with short lags between investment and outcomes, and adoption. It also discourages specialisation of scientists and other resources in areas of work where sustained funding may be uncertain, even when these areas have high pay-off potentials.

Policy-relevant realities of agricultural R&D

Innovation in agriculture has many features in common with innovation more generally, but also some important differences. In many ways the study of innovation is a study of market failure and the individual and collective actions — notably investing in agricultural R&D — taken to deal

[6] Notably, government agencies accounted for over half the publicly performed agricultural R&D in the United States through to the mid-1900s, but the university share has grown steadily since then (Alston *et al.* 2010).

with it. Like other parts of the economy, agriculture is characterised by market failures associated with incomplete property rights over inventions. The atomistic structure of much of agriculture means that the attenuation of incentives to innovate is more pronounced (and particularly so in many of the poorest parts of the world where the average farm size is small, and getting smaller) than in other industries that are more concentrated in their industrial structure. On the other hand, unlike most innovations in manufacturing, food processing or transportation, agricultural technology has a degree of site specificity because of the biological nature of agricultural production, in which appropriate technologies vary with changes in climate, soil types, topography, latitude, altitude and distance from markets. The site-specific aspect circumscribes, but by no means removes, the potential for knowledge spillovers and the associated market failures that are exacerbated by the small-scale, competitive, atomistic industrial structure of agriculture.

Agricultural R&D benefits are difficult to appropriate, especially in developing countries

The partial public-good nature of much of the knowledge produced by research means that research benefits are not fully privately appropriable. Indeed, the main reason for private-sector underinvestment in agricultural R&D is inappropriability of some research benefits: the firm responsible for developing a technology may not be able to capture (i.e., appropriate) all of the benefits accruing to the innovation, often because fully effective patenting or secrecy is not possible or because some research benefits (or costs) accrue to people other than those who use the results. For certain types of agricultural research, the rights to the results are fully and effectively protected by patents or other forms of intellectual property protection, such that the inventor can capture the benefits by using the results from the research or selling the rights to use them; for instance, the benefits from most mechanical inventions and developing new hybrid plant varieties, such as hybrid corn, are appropriable. Often, however, those who invest in R&D cannot capture all of the benefits — others can 'free-ride' on an investment in research, using the results and sharing in the benefits without sharing in the costs.[7]

In such cases, private benefits to an investor (or group of investors) are less than the social benefits of the investment and some socially profitable investment opportunities remain unexploited. The upshot is that, in the absence of government intervention, investment in agricultural research is likely to be too little.

The types of technology often suited to less-developed country agriculture have hitherto been of the sort for which appropriability problems are more pronounced — types that have been comparatively neglected by the private sector even in the richest countries. In particular, until recently, private research has tended to emphasise mechanical and chemical technologies, which are comparatively well protected by patents, trade secrecy and other intellectual property rights; and the private sector has generally neglected varietal technologies except where the returns are appropriable, as for hybrid seed. In less-developed countries, the emphasis in innovation has often been on self-pollinating crop varieties and disembodied farm management practices, which are the least appropriable of all. The recent innovations in rich-country institutions mean that private firms are now finding it more profitable to invest in plant varieties; the same may be true in some less-developed countries, but not all countries have made comparable institutional changes.

Agricultural R&D lags are especially long

The lags between investing in R&D and realising a return from that investment are long, often spanning decades, not months or years. The dynamic structure linking research spending and productivity involves a confluence of processes — including the creation and destruction of knowledge stocks and the adoption and disadoption of innovations over space and time — each of which has its own complex dynamics. That science is a

[7] For instance, an agronomist or farmer who developed an improved wheat variety would have difficulty appropriating the benefits because open-pollinated crops like wheat reproduce themselves, unlike hybrid crops, which do not. The inventor could not realise all of the *potential* social benefits simply by using the new variety himself; but if he sold the (fertile) seed in one year the buyers could keep some of the grain produced from that seed for subsequent use as seed. Hence the inventor is not able to reap the returns to his innovation.

cumulative process, in which today's new ideas are derived from the accumulated stock of past ideas, influences the nature of the research–productivity relationship as well. It makes the creation of knowledge unlike other production processes. The evidence for these long lags is compelling. One form of evidence is the result of statistical efforts to establish the relationship between current and past R&D spending and agricultural productivity. The dozens of studies done to date indicate that the productivity consequences of public agricultural R&D are distributed over many decades, with a lag of 15–25 years before peak impacts are reached and continuing effects for decades afterwards.[8]

The statistical evidence linking overall investments in aggregate agricultural R&D to agricultural productivity growth are reinforced by the other evidence about research and adoption lag processes for particular technologies, especially crop varieties about which we have a lot of specific information. For example, hybrid corn technology, which took off in US farmers' fields in the 1930s, had its scientific roots in focused research that began in 1918 (and arguably before then, at least to the early 1890s). Thus the R&D or innovation lag was at least 10 years and may have been 20–30 years. The time path of the adoption processes extends the lag lengths even further. Iowa had 10% of its corn acreage planted to hybrids in 1936 (with 90% of its corn acreage so planted just four years later), while it took until 1948 before Alabama — a state with distinctive agroecological attributes compared with the principal Corn Belt states — had 10% of its corn acreage under hybrids. By 1950, 80% and by 1960, almost all of the corn grown in the US was hybrid corn. Looking across all the states, the technology diffusion process was spread over more like 30 years, reflecting the envelope of adoption processes that were much more rapid in any individual state. Taking the entire research, development, and adoption process for hybrid corn as having begun as late as 1918, the total process that had been accomplished by 1960 took place over a period of at least 40 years and possibly decades longer.

Has modern (bio-)technology materially sped up this research–innovation–adoption process, as is commonly suggested? Consider, for example, the development and uptake of genetically engineered (GE) corn in the United States.

GE corn was first planted on US farmers' fields in the mid-1990s. The adoption–cum–diffusion process for GE crops is not yet complete, the technology itself is continuing to evolve, and the maximum adoption rate has not yet been achieved, but by 2008, 80% of the US corn area was planted to GE varieties. Like hybrid corn, biotech corn has been adopted at different rates in different states, but perhaps for different reasons. This, as yet incomplete, process over less than 15 years represents only part of the relevant time lag. To that we must add the time spent conducting relatively basic and applied research to develop and evaluate the technology, and the time (and money) spent after the technology had been developed to meet the requirements for regulatory approval by a range of government agencies.

Compared with the adoption–cum–diffusion process for hybrid corn within the United States, the process for biotech corn appears to have been a little faster. Biotech corn achieved 80% adoption within 13 years compared with 19 years for hybrid corn. Other elements of the process, however, may be getting longer. For instance, the process of regulatory approval may have added a further 5–10 years to the R&D lag (and this regulatory approval lag for biotech crops appears to be getting longer). Given a range of 10–20 years spent on R&D to develop the technologies that enabled the creation of biotech crops, and then the time spent to develop the initial varieties and improve them, the overall process of innovation in the case of biotech corn may have taken 20–30 years so far.

Agricultural R&D spills over, but not equally everywhere

Underfunding of agricultural R&D in developing countries is clearly problematic, and the stage is set for the problem to worsen. In addition to the distinctive features of developing countries described above, the inadequacy of agricultural knowledge stocks may be exacerbated by changes occurring in developed countries. While the most immediate and tangible effect of the new technologies and ideas stemming from research done

[8] Alston *et al.* (2010 — see also footnote 9) reviewed the prior literature. They also developed their own estimates using newly constructed US state-level productivity over 1949–2002 and US federal and state spending on agricultural R&D and extension over 1890–2002. Their preferred model had a peak lagged research impact at year 24 and a total lag length of 50 years.

in one country is to foster productivity growth in that country, the new technologies and ideas often spill over and spur sizable productivity gains elsewhere in the world. In the past, developing countries benefited considerably from technological spillovers from developed countries, in part because the bulk of the world's agricultural science and innovation occurred in rich countries.[9] Increasingly, spillovers from developed countries may not be available to developing countries in the same ways or to the same extent.

Decreasing spillover potential is caused by several related market and policy trends in developed countries.

First, the types of technologies being developed may no longer be as readily applicable to developing countries as they were in the past. As previously noted, developed country R&D agendas have been reoriented away from productivity gains in food staples toward other aspects of agricultural production, such as environmental effects, food quality, and the medical, energy and industrial uses of agricultural commodities. This growing divergence between developed-country research agendas and the priorities of developing countries implies fewer applicable technologies that would be candidates for adaptation to developing countries.

Second, technologies that are applicable may not be as readily accessible because of increasing intellectual property protection of privately owned technologies and, perhaps, more importantly, the expanding scope and enforcement of biosafety regulations. Different approaches may have to be devised to make it possible for countries to achieve equivalent access to technological potential generated by other countries.

Third, those technologies that are applicable and available are likely to require more substantial local development and adaptation, calling for more sophisticated and more extensive forms of scientific R&D than in the past. The requirement for local adaptive research is also likely to be exacerbated as changes in global and local climate regimes add further to the need for adaptive responses to those changed agricultural production environments. In some instances developing countries may also have to extend their own agricultural R&D efforts farther upstream, to more fundamental areas of the science. These new pressures for self-reliance in agricultural research are coming at a time when many developing countries, along with developed countries, are finding it difficult to sustain the current rates of investment in agricultural research.

Economies of size, scale and scope in agricultural R&D

In evaluating the extent of underinvestment in agricultural R&D and potential means of increasing investment, it is important to consider the economies of size, scale and scope in knowledge accumulation and dissemination. For instance, if technological spillovers continue to be fairly available and accessible, as they have been in the past, it might not make sense for small, poor, agrarian nations to spend their scarce intellectual and other capital resources in agricultural science. However if spillins from developed countries decrease, developing countries will need to conduct more of their own research, but many nations may be too small to achieve an efficient scale in many, if any, of their R&D priority areas. For example, 40% of the agricultural research agencies in Sub-Saharan Africa employed fewer than five full-time-equivalent researchers in 2000; 93% of the region's agricultural R&D agencies employed fewer than 50 researchers. Creative institutional innovations to collectively fund and efficiently conduct the research in ways that realise these scale and scope economies will be crucial.

Concluding remarks

Correcting for market failures is a primary justification for government action. Past efforts to correct for the pervasive tendency for private markets to underinvest in agricultural R&D in Australia include path-breaking institutional innovations that restructured the funding of agricultural R&D via joint industry–government efforts overseen by the Research and Development Corporations (RDCs), and, more recently, end-point royalty schemes to pay for the research embodied in new crop varieties. These investments have had high social payoffs both within Australia and globally, and have certainly been instrumental in alleviating hunger for many of the world's poor. But global food security concerns are again on the rise while the pace of agricultural productivity growth is slowing. Moreover, recent developments in the amount and orientation of

[9] Developed countries have also benefited substantially from spillins of R&D done in or directed toward the developing world. Alston (2002) reviewed work by economists in quantifying these benefits.

agricultural R&D are likely to exacerbate the slowdown in agricultural productivity growth and add to environmental stresses and food-security concerns in the decades ahead.

Revitalised funding and improved institutional and evidence-based oversight of the disbursal of those funds for both domestic and international agricultural R&D initiatives would go a long way to redressing the productivity slowdown that is apparent in recent years. However, just as Australian agricultural R&D effects spill across state borders, thus making an Australia-wide perspective appropriate for conceiving and managing agricultural R&D (including the joint state and federal government and agricultural industry roles now in place), the international spillover dimensions of agricultural R&D are also important. Moreover, as the global policy landscape concerning food security, international trade and climate change takes on ever-increasing importance, domestic policy decisions concerning agricultural research will, or at least should, increasingly be made with an eye to their international implications. Likewise, Australia's international commitments to food security, international trade and climate change agendas will increasingly circumscribe domestic policy choices and actions. This will require making these international implications more explicit in the domestic institutional and policy environments, not only regarding the details of the deployment of funds to conduct agricultural R&D (via the RDCs and other agencies) but also the roles and responsibilities of the institutions carrying out the research (including CSIRO, the international agricultural research centres and Australian universities). Creative engagement of the public and (agribusiness) private sectors will be an important part of this revitalised agricultural R&D landscape.

An important lesson from the past, however, is that the lags between investing in agricultural R&D and realising a social return on these investments are long (typically several decades or more), and they remain so. Thus deploying funds via conventional project cycles (lasting 3–5 years) is inappropriate, at least for some of the key strategic research required to spur growth in global food and feed supplies. A sustained (but managed and flexible) commitment is required. If history is any guide to the future, that persistence will be rewarded with high and life-changing payoffs globally, and to Australian domestic agricultural and international development interests in
particular.

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Fertility and Fertiliser Research and Development

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So far, world food supply has managed to stay ahead of rising population due to increasing productivity and a modest expansion of cultivated area. However, finite resource reserves, the increasing cost of energy and the increasing environmental cost of opening new land pose new challenges. Africa is a special case where increased food production has come mainly from expansion of farmland, while low fertiliser use and extensive soil mining have retarded productivity.

Recent limited public–private initiatives show promise of reversing this low productivity. Global food security depends on a focused effort to increase production of food crops; in this effort fertiliser must play an important part. Government policy must be supportive of the provision of purchasing power support for smallholder farmers using such instruments as vouchers.

The production agronomic performance of current fertiliser products is quite inefficient and must be improved. New products using new resources must be developed. Much of the nutrient content of current fertiliser products is wasted at high cost to the environment because only 30–40% is absorbed by crops. This can be improved by better application techniques and improved products, and by improving crop attributes. There is also ample scope for increased use of nutrient-bearing waste products. Nanotechnology and biotechnology open new opportunities for collaborative research between the public and private sectors. For the world to be provided the next generation of fertilisers, the private sector must play a significant role — in partnership with public institutions.

DR AMIT H ROY, IFDC President and CEO since 1992, came to IFDC as a chemical engineer in 1978. Under his leadership, IFDC — an International Center Creating Food Security and Agricultural Sustainability — expanded its mission to address not only food security but also trade, equity and the environment. Leading IFDC from fertiliser to agribusiness and economic development, he instituted research and development of new or modified fertiliser materials and processes using indigenous sources, especially phosphate rock. Roy encouraged the development of fertiliser industries in many developing countries and provided needed technical assistance. He played a key role in organising the landmark Africa Fertilizer Summit held in Abuja, Nigeria, in June 2006.

Introduction

The world has so far managed to avoid the Malthusian catastrophe through great leaps in agricultural yields from agricultural extension (bringing new land into cultivation) and innovations in fertiliser, pesticides and crop breeding. However, whether the food supply will be able to keep pace with exponential increases in world population remains a pertinent question. According to the World Watch Institute (2009), the world population stood at 6.8 billion in early 2009 and could reach 9.4 billion by 2050. More than 95% of the population growth is occurring in Africa and Asia, which already account for three-fourths of the global population (Fig. 1).

There is certainly a finite limit to the availability of arable land. Even though there remains land that could be converted to agricultural production, particularly in Africa, the environmental cost of doing so is increasing. These costs include the ensuing release of stored carbon into the atmosphere, as well as the destruction of animal habitat and biodiversity. Over the last half-century, Africa and Asia have differed markedly from one another in their method of increasing food production. As

can be seen in Figure 2, productivity (as measured by grain yield) has lagged in Africa, while in Asia and the rest of the world it has been steadily increasing. Figure 3, which compares Sub-Saharan Africa (SSA) with South Asia, shows clearly that Africa has relied primarily on the opening of new land for increased production. In Asia, the main challenge remains how to maintain steady yield growth in the face of diminishing marginal returns to agricultural inputs. In Africa, the main challenge is how to reduce the delivered cost of plant nutrients so that farm intensification becomes economically preferable to opening new land.

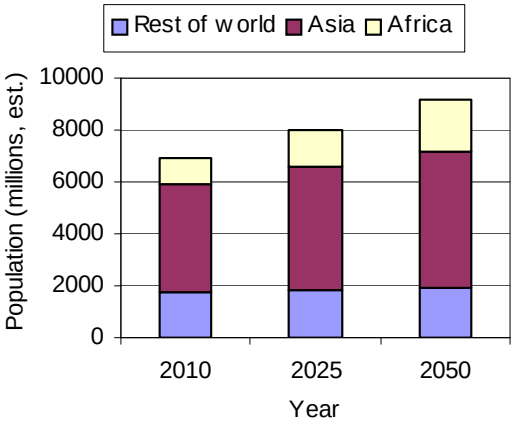

Figure 1. Population growth forecasts (Source: United Nations 2008)

Rationale

This paper argues that fertiliser research and development can make a major contribution in addressing the food security challenges faced by both Asia and Africa. Public-sector fertiliser research and development, particularly in the United States during a three decade period starting in the early 1940s, was the primary contributor to the fertiliser production processes and products that are prevalent today. That era in fertiliser research and development has been a prime driver of growth in global agricultural productivity. The fertiliser technology research was supported and influenced by agronomic and economic research programs, including the programs of the international agricultural research centres and national agricultural research institutions. Today there is

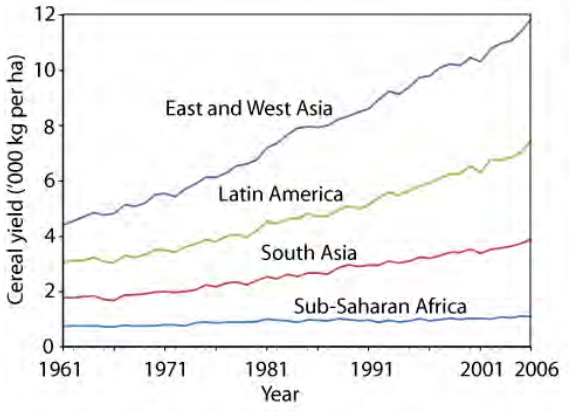

Figure 2. Cereal yields in different developing regions from 1961 to 2007 (Source: Derived from FAO data)

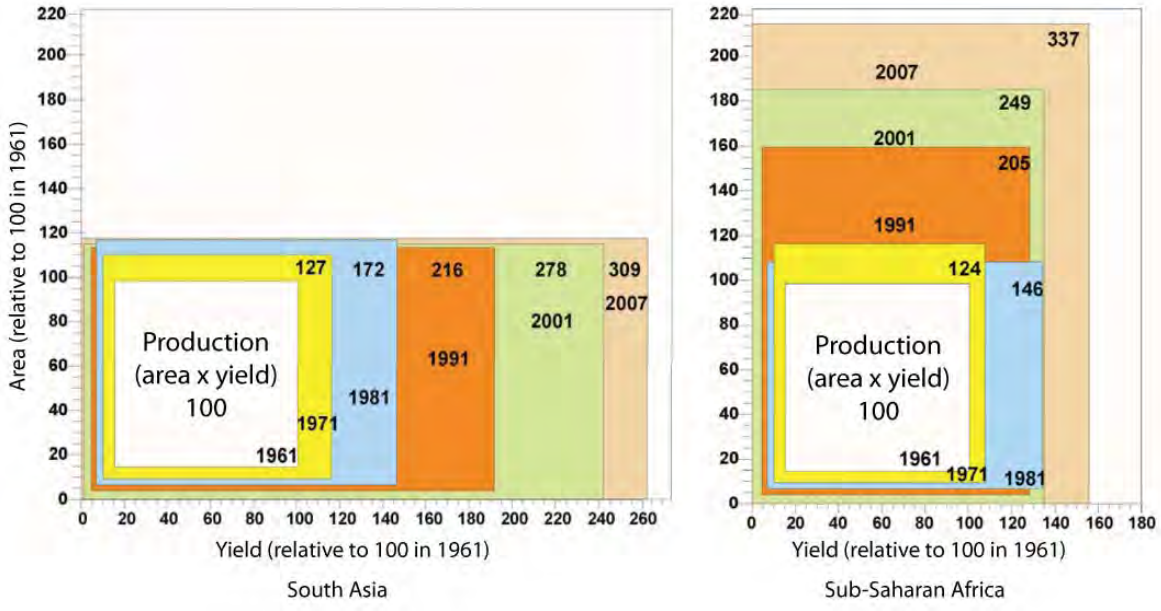

Figure 3. Relative growth of cereal yield per unit area and area in cereal production in South Asia and Sub-Saharan Africa between 1961 and 2007 (1961 = 100 for yield, area and production) (Source: IFDC)

growing emphasis on the need for the private sector to take on a more prominent role. The question is, can private-sector research and development (R&D) on soil fertility and fertiliser products reach the poor? What role can the private sector play in research to address the needs of poor farmers?

The matter is complex for a number of reasons. First, the private sector must have the incentive to do such research. Thus far, the incentive is lacking because poor farmers do not constitute a viable market justifying private-sector investment in R&D targeted at them. Second, the private sector must have the capacity to do such research. This capacity requires funds, staff with knowledge of the issues at hand and physical infrastructure (facilities, equipment). Currently, the private sector in developed countries is doing little or no research on soil fertility and fertiliser products that can be marketed to poor farmers. And, even if the products of private-sector research were targeted to the needs of poor farmers, there remains the challenge of the poor farmer being able to afford them at market prices. In general, private firms in the fertiliser industry focus their research programs on achieving advances that will yield the greatest economic return to the firm. Improving process technology (to achieve production, economic and performance efficiencies) and product technologies that provide the firm some comparative advantage in terms of improved product performance (in their target market or allowing for improved economic use of an asset) are two priority concerns that significantly influence private-sector research efforts. In addition, any research the private sector does is proprietary research or market research owned exclusively by the firm paying for it.

The development and adoption of fertiliser products and soil fertility management technologies for poor farmers hinges on the capacity of the actors of the so-called research triangle (the private sector, the public sector and international agricultural research centres) to productively interact. It will be increasingly important for all of these actors to collaborate to develop technologies that are adapted to the biophysical constraints and socio-economic characteristics of smallholder farmers. Two fundamental questions are relevant to the success of a research triangle to improve agricultural productivity in developing countries:

- What are the key soil fertility issues that smallholder farmers face?
- How can research on soil fertility and fertilisers address these issues?

The objective of this paper is to provide an overview of the soil fertility issues faced by poor farmers in Asia and Africa, share best practices on public–private sector collaboration for technology and market development, and put forward some answers as to how research can help mitigate some of these issues.

Soil fertility issues for poor farmers

The long-term decline in ecosystem function and land productivity, or land degradation, is gaining in severity and extent for poor farmers (Fig. 4). According to recent studies by the Food and Agriculture Organization of the United Nations (FAO), an estimated 1.5 billion people, or a quarter of the world's population, depend directly on land that is being degraded (FAO 2009). In Africa, land degradation affects an estimated 485 million people, resulting in losses of about $42 billion in income and 6 million hectares (ha) of productive land each year (Bationo *et al.* 2006).

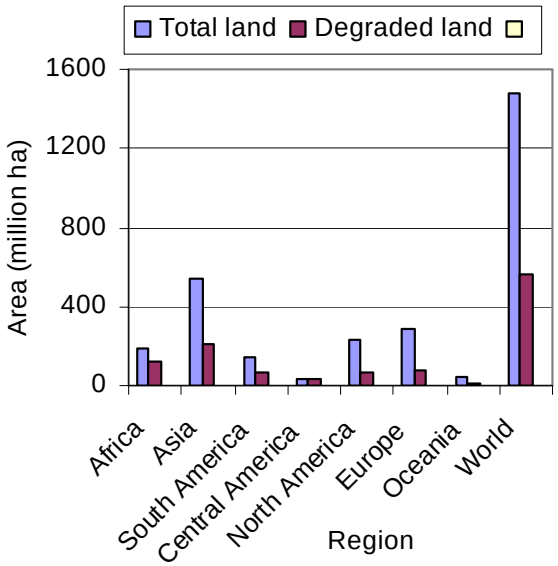

Figure 4. Global estimates of agricultural land degradation by region (Adapted from Bationo *et al.* 2006)

The soils in Sub-Saharan Africa (SSA) are naturally fragile (parent material, climate). Sixteen percent of all soils in Africa have low nutrient reserves, while in Asia the equivalent figure is only 4%. Henao and Banaante (2006) have shown that the number of African countries with average nutrient depletion rates exceeding 60 kg ha^{-1} y^{-1} increased from 12 in 1995–1997 to 19 in 2002–2004. Table 1 presents the main soil fertility constraints faced by poor farmers in Africa.

Table 1. Soil fertility constraints in Africa (Adapted from Bationo *et al.* 2006)

Soil type	Countries	Soil fertility constraints
Ferrasols	Angola, Burundi, Cameroon, Central African Republic, DRC, Rwanda, South Sudan, Uganda and Zambia	Low retention capacity Deficiencies in Ca, Mg and K
Acrisols	Benin, Southern Cameroon, Côte d'Ivoire, Southern Ghana, Nigeria, Tanzania and Togo	Low mineral reserves Deficiencies in boron and Mg Leaching
Nitrosols	Eastern DRC, Ethiopia, Kenya and Tanzania	Mg toxicity
Lixisols	Parts of West and Southeast Africa, Madagascar	Low capacity to store nutrients Deplete quickly under farming
Arenosols	Angola, Botswana, Chad, Southwest DRC, Central Mali, Mauritania, Southern Niger, Senegal and Sudan	Low water-holding capacity Low nutrient retention capacity Deficiencies in Zn, Mg, Fe, Cu, S, K
Vertisols	Parts of Ethiopia, Sudan and Tanzania	Flooding and erosion
Gleysols and Fluvisols	Equatorial Africa	Acidity

Land degradation has been attributed to many factors. Population pressure has been a main driver of land clearing for cultivation and consequently deforestation. Shifting cultivation without fallows or proper soil management and cultivating marginal lands causes nutrient mining. Overgrazing of livestock and the ensuing reduction in land cover leaves the soil vulnerable to wind and water erosion. Climate change, particularly through rising sea levels and seawater inundation, has lead to increased salinity in soils.

To mitigate the impact of land degradation on soil nutrients, farmers apply fertilisers. As seen in Figure 5, Asia has the highest rate of fertiliser use, whereas SSA has the lowest. This suggests significantly different implications for the two regions. In Asia, the urgent need for increased crop productivity cannot be met by simply applying more fertiliser. Rather, the production functions of major crops must be shifted by technological advancement. In Africa, where fertiliser application is so low, the case could be made that no new technology is needed until the genetic potential of existing crops is being more nearly realised through the increased and judicial use of fertiliser and other inputs.

The problem, however, is that fertiliser is relatively more expensive in Africa and often inaccessible to the millions of small farmers. The average retail price of urea fertilisers in coastal African countries is 50% higher than in an Asian country. In Thailand the average retail price of urea fertilisers is $282/metric tonne compared with $453/mt in coastal African countries (Ghana, Mozambique and Tanzania) and $515 in landlocked African countries (Malawi, Mali and Uganda) (Chemonics and IFDC 2007) (Fig. 6). Furthermore, the inefficient use of fertiliser products by poor farmers also constitutes a serious problem. For instance, smallholders' current practices of hand-broadcasting urea in rice fields leads to less than 30% of the applied N being used by the plant.

Best practice in public–private sector collaboration for fertiliser technology and market development

One ‘pocket of success’ in public–private-sector partnerships that target fertiliser technology and soil fertility management for smallholder farmers is the case of urea supergranule (USG) technology and fertiliser deep placement (FDP) in Bangladesh. Like most smallholder farmers in Asia and Africa, Bangladesh farmers are resource-poor and risk-adverse. Technology introduction in such an environment often has a slow return to invested capital, a deterrent to major private-sector investment.

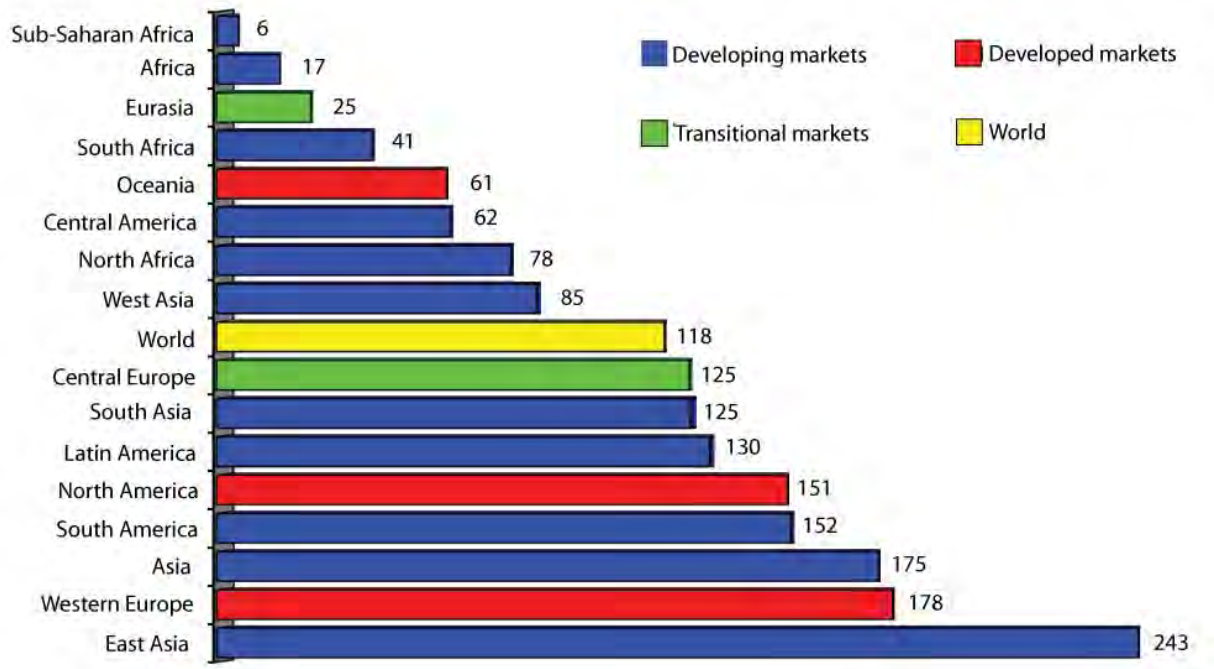

Figure 5. Average rates of NPK use in various markets (kilograms per hectare), 2007–2008 (Source: FAO data)

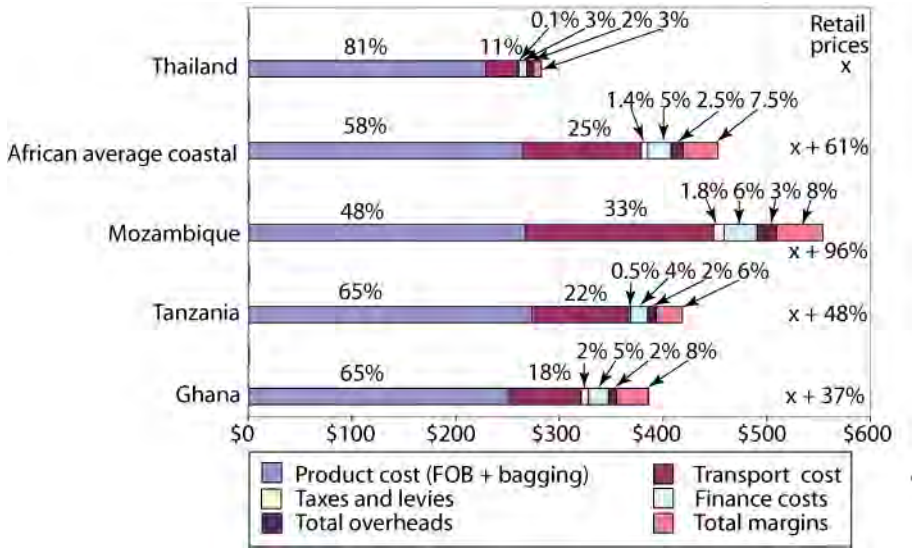

Figure 6. Fertiliser cost chain comparison of African coastal countries with Thailand (Source: Chemonics and IFDC 2007)

During the past two decades, IFDC scientists have worked with the public sector (e.g., Bangladesh Ministry of Agriculture and the Bangladesh Rice Research Institute) and the private sector (e.g., small private entrepreneurs) to develop FDP technology based upon USG. The technology, initially targeting rice farmers, involved:

- applied research to modify conventional urea fertiliser so that it was readily adapted to point placement by hand in flooded rice
- agronomic research to determine the agronomic efficiency of the USG and FDP
- economic research to assess the economic performance of the FDP technology and USG.

The benefits of the technology are significant: improved yields of up to 30% while using 30–35% less urea than conventional urea broadcast methods. In addition, the environmental consequences of the technology are positive, with less urea applied and lower losses to the atmosphere and ground water.

The public–private sector partnership that contributed to FDP and USG development and introduction is based on supply by small microenterprises. IFDC designed a small-scale briquetter to compact conventional urea fertiliser particles into briquettes of up to 2.7 g by weight. And private, locally owned metal fabrication shops improved upon the design and started to fabricate and market the machines to local entrepreneurs at prices equivalent to only $1500 per machine. In the past three months, at least one major urea factory in Bangladesh has started to assess the feasibility of a factory modification to mass produce the supergranules. The Bangladesh government has fully embraced the technology as a centerpiece in its agriculture strategy.

Another best practice in public–private partnerships that fostered fertiliser market development was achieved through the application of the Competitive Agricultural Systems and Enterprises (CASE) approach in West Africa. CASE is a market-driven approach that strengthens the innovative capacities of and coordination between the private sector (importers and dealers), research and extension services, lending institutions and market information systems. The approach stresses farmer participation in technology development, integrated soil fertility management (ISFM) and the development and strengthening of commodity chains. Strengthening the linkages among farmers and commodity and fertiliser traders is a critical component of the CASE approach. IFDC and partners have used this approach for the last five years to promote fertiliser market development and improve agricultural productivity in seven West African countries: Benin, Burkina Faso, Ghana, Mali, Niger, Nigeria and Togo. Presently, more than 100 000 farmers have adopted ISFM technologies. On average, agricultural productivity has more than doubled and farm-level incomes have increased by 20–50%. The value : cost ratios of adopted ISFM options are well above 2.

Addressing soil fertility issues through research

To address the soil fertility issues faced by poor farmers in Africa, it is important that public–private partnerships focus on research to improve the efficiency of fertiliser use, reduce the farm-gate price of fertiliser for smallholder farmers and develop new products that yield economic and agronomic benefits incremental to the current range of products.

Improving fertiliser-use efficiency

Reducing nutrient losses is a critical step towards improving soil fertility and agricultural productivity for poor farmers. It makes sense from every perspective — agronomic, economic and environmental. A critical question, however, is whether the private sector is interested in conducting research to improve fertiliser-use efficiency. The private sector may not have the incentive to improve nutrient-use efficiency because of the potential negative impact on their market shares or sales. However, declines in fertiliser sales may be only a short-term impact of improved nutrient-use efficiency. In the long term, farmers will see and reap the benefits of fertiliser use, leading to scaling-up and adoption of fertiliser technologies in rural areas. In addition, improving fertiliser-use efficiency is not just the issue of less fertiliser use (lower product sales by companies) but their role in protecting the environment. Hence, fertiliser companies can use the environmental agenda to their benefit in terms of marketing their products. A new generation of farmers is very keenly aware of their role in protecting the environment.

The key to improving fertiliser-use efficiency is research oriented towards developing site-specific nutrient management packages. Five methods of fertiliser application are currently known that can improve fertiliser-use efficiency for poor farmers:

Banding

Banding a fertiliser close to the seed row (Fig. 7) has been shown to improve the uptake of nutrients contained in that fertiliser (Ohio State University 2009). This technique stimulates early growth of seedlings, increases the availability of phosphates to crops grown in acidic soils where fixation of phosphates is a problem and promotes early root development. Under rainfed conditions, where extensive and deeper root development conditions prevail, banding will enable plants to draw moisture from lower depths of soil and better withstand drought.

Fertigation

Fertigation (Fig. 8) saves money by combining the tasks of applying water and fertiliser and allows growers to fertilise crops throughout the growing season rather than stop when the plants become too unwieldy to allow mechanised applications with conventional machinery. Many crops can thrive with less fertiliser when it is applied through fertigation (United States Department of Agriculture 2004).

Figure 7. Ron Smith banding using NPK Granules in IFDC's greenhouse

Integrated soil fertility management

This involves the integrated use of inorganic fertilisers and soil amendments, such as organic matter, lime and phosphate rock. Such soil amendments interact with mineral fertilisers to improve the soil quality, including organic matter status, tilth, water-retention capacity, pH and available P. ISFM does not completely rely on organic manure and amendments to provide all plant nutrient needs as is the case with organic farming. The ISFM approach improves the release and availability of nutrients from organic sources by modifying the C:N:P ratio and increasing the efficiency of applied mineral fertilisers. This is done through increased nutrient and water retention, increased microbial activity and increased root development. Soil compaction and poor root development are among the major causes for poor nutrient- and water-use efficiency. ISFM thus makes the soil hospitable for better crop growth.

Figure 8. Fertigation — IFDC/Agrium field trials in Ghana

Controlled-release nitrogen fertilisers (CRF)

These are fertiliser compounds that release either by design or naturally their nitrogen content over an extended period of time. CRFs can and do prevent losses of N fertiliser by matching, to the extent possible, N supply with crop demand. They can be effective tools to chemically or physically influence the movement and transformation of N in order to reduce losses. The major constraint associated with widespread use of CRFs on food crops is the cost of the commercial products. Unless the costs of production can be reduced significantly or the potential benefits found to be greater than expected, CRFs may not be a practical solution. Therefore, medium-term research is needed to develop more cost-effective technology for controlled- or slow-release fertilisers.

Figure 9. IFDC's FDP field trials on rice in Rwanda

Fertiliser deep placement technology (Fig. 9)

As described above, FDP is a simple yet innovative technology that provides a unique opportunity for sustainable agricultural development in many rice-producing countries. FDP involves the placement of 1–3 g USG or briquettes at a soil depth of 7–10 cm shortly after transplanting rice. The FDP technology addresses the challenge of low productivity in rice ecologies by increasing nitrogen-use efficiency. Deep placement of urea eliminates nitrogen losses due to volatilisation, leaching and floodwater runoff, allowing farmers to realise a 30% increase in yields over the same nitrogen when conventionally applied. FDP also ensures N availability beyond the flowering stage due to higher amounts of available N, encourages algal biological nitrogen fixation because of low floodwater N concentration and reduces weed competition. Research is needed in this area to acquire a basic understanding of the nutrient quality of the soil prior to fertilisation.

Reducing the farm-gate price of fertilisers for smallholders in Africa

Finding ways to reduce the delivered cost of crop nutrients should constitute a high priority for research in Africa. Improving value-chain efficiencies can contribute to lower transaction costs and, when combined with market efficiencies, contribute to lower margins and lower farm-gate prices. That may not be sufficient, however, to enable smallholder farmers to buy the soil nutrient management materials needed. Input-voucher programs are a pro-poor farmer, market-friendly means of providing either direct 'market-smart' subsidies or crop production credit to resource-poor farmers (Fig. 10). These programs have been implemented by IFDC in Afghanistan, Malawi and Nigeria. Integral characteristics of voucher programs are the provision of technical assistance and training to both the recipient farmers and private-sector agro-dealers and the targeting of voucher recipients. Voucher programs are generally backed by a declining smart subsidy designed to overcome the risk aversion associated with new technology adoption, to offset the rising cost of fertiliser and to build a commercial support system for a sustainable business model.

Moreover, smallholder farmers' access to fertiliser markets can also be improved through wider dissemination of market information and greater transparency. Research is needed in this area to determine communication channels that are adequate for rural areas and the most cost-effective ways for farmers to access market information. IFDC is currently developing the AfricaFertilizer.org web site, an on-line platform that will serve as a global internet forum on fertilisers for Africa (Annequin 2009) (Fig. 11). The site will provide timely information on many aspects of fertiliser products, including production, trade, prices, actors and fertiliser news.

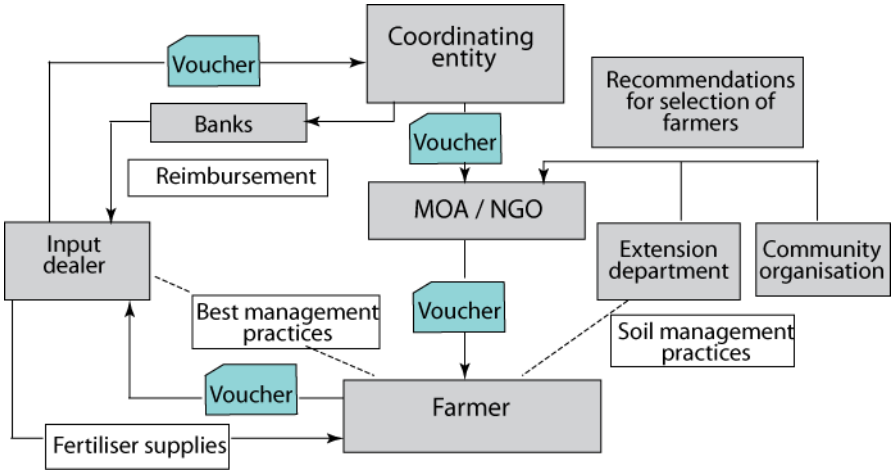

Figure 10. Schematic diagram of the targeted voucher system

Figure 11. Current mock 'AfricaFertilizer.org Website' – www.shoalsweb.com/IFDC/Africa_Fertilizer/index.html

Developing the next generation of fertiliser products

Given the dramatic food and fertiliser crisis events of the past few years and the growing awareness that the key non-renewable raw materials needed for fertiliser manufacture are being depleted, the time has come for a bold and new research initiative to create the next generation of fertilisers. The need for new and innovative research is a global issue; it requires a global solution. However, the key constraints to a typical 'start-up' fertiliser research and development initiative are limited time and financial resources. Assembling a multidisciplinary staff of scientists and engineers, along with construction of laboratories and pilot plants, is a daunting task that would be both costly and time-consuming.

To address the above constraint, IFDC will provide leadership and serve as the hub for a 'Virtual Center of Excellence for Fertilizer Research and Development' (VRC). The centre will bring together the best scientific, business and governmental minds to focus on creating a research system that challenges the current state of knowledge and considers new and non-traditional paradigms. The model for pursuing this new generation of research focuses on:

- modifying and improving existing fertiliser products and technologies
- developing and incorporating new fundamental concepts and methods to generate viable fertiliser products and technologies
- developing and institutionalising a global approach to create, monitor and sustain a universal research agenda.

Conclusions

Meeting the food security needs of low-income households will require close collaboration between the private sector and public institutions. Together, they will need to undertake research and development targeted at reducing the farm-gate price of fertilisers, improving fertiliser efficiency and developing the next generation of fertiliser

products. Under the umbrella of the VRC, scientists from the public and private sector have the potential to develop technologies to create new fertiliser products from a variety of natural and man-made resources around the world. Research areas range from developing a high-quality granular fertiliser product from various nutrient-rich by-products, producing fertilisers using waste streams from coal-combustion power plants, finding more efficient and effective technologies that are less fossil-fuel dependent and developing genetic modification technologies of farm crops that will increase plant uptake from soil and the new generation of fertiliser products.

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Livestock and their Health Products and Services

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The contributions of livestock to food security and poverty alleviation are coming under increasing international scrutiny, particularly as livestock producers are also challenged to respond to global warming and the emergence of new diseases. Research is vital to increase efficiency of production, to understand the importance of livestock in agricultural systems and to protect animals and people through disease control programs. For animal health research one of the challenges is to balance public and private efforts and ensure that the demands for livestock and human health are met.

Lack of incentives for cooperation between the private and public sector has lead to the neglect of some important livestock diseases (for example some tick-borne diseases) and of livestock diseases than can infect people (for example brucellosis) that remain prevalent in many poor countries in Asia and Africa.

New approaches are required to increase the effectiveness of private–public cooperation in developing new products including vaccines, drugs and diagnostics. Among these new approaches the Global Alliance for Livestock Veterinary Medicines (GALVMed) builds relationships at the outset of research and continually manages the partnership when results emerge, products are evaluated and opportunities arise.

A second approach is to improve the access of poor livestock keepers to the markets for their livestock which in turn provides access to animal health products and the technical support to use them effectively. Australia supports projects to increase market access for livestock products and animal health inputs in many Asian and African countries.

The combination of these approaches — improving the supply of appropriate product from industry, and enhancing access of poor farmers to markets — builds new pathways for research to deliver benefits to the poor.

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Introduction and background

Livestock agriculture represents 33% of global agricultural gross domestic product and both production and consumption of meat are increasing rapidly in developing countries. In 1980 meat consumption in developed countries was five times that that of developing countries. Now they are equal. By 2030 it is forecast that developing country consumption will be double that of developed countries (World Bank 2009).

Against this background, livestock production attracts attention in current debates on food security, global greenhouse gas emissions and as a source of diseases that can affect humans. The context of that attention is often negative while dismissing the essential contributions that livestock make by, for example, reducing the risks from droughts and diseases that affect crop pro-

duction, their ecological role in conversion of crop and industrial by-products, and the positive health effects of protein and micronutrient supply (Steinfeld *et al.* 2006; World Bank 2009).

Epidemics of livestock disease attract widespread attention when they affect trade, disrupt travel or offend public standards for animal welfare. In developing countries, global attention focuses on human losses and disruption of international travel and trade. However, these dramatic occurrences are insignificant compared to the cost of chronic and endemic diseases that are rarely fully quantified and are a recurring yearly loss. The main approaches at the disposal of livestock managers and veterinarians are effective quarantine and biosecurity, good husbandry and a sound understanding of the needs of productive, healthy stock. The vaccines and chemical drugs available through private and public supply chains are vital tools in such effective health management. This paper deals with the supply of animal vaccines and attempts to identify gaps in both product development and supply for livestock production in developing countries, and describes two new approaches to enable the private and public sectors to work together to fill these gaps.

Professional and sectoral barriers

In the early 1980s a typical meeting of agricultural researchers with livestock producers would often be characterised by arguments between the professions: breeders arguing with nutritionists arguing with veterinarians about which approach was most likely to increase productivity or prevent disease. The scientific fields of genetics, nutrition, vaccine and drug development were advancing so quickly that expectations of 'silver bullets' in each of these fields were high. Economists at such meetings would present partial budgets but lack good data on the costs of disease. Soil and water scientists, market analysts and retailers were mostly not part of the debate. Thirty years later and most such industry forums have animal scientists, economists, veterinarians, water and soil scientists, butchers and retailers all 'on the road' together, facing outwards towards the producers, consumers and taxpayers that support their research.

Even more recently there has a been a further convergence, with the fields of environmental health, animal health and human health considered inseparable in what has been variously described as described as the 'One Health', 'Eco Health' or 'One World, One Health' (Wildlife Conservation Society 2004; Anon. 2008). This further change has been driven by improved understanding of the links, for example, between viral diseases in livestock and humans, and in the realisation that there are common approaches, for example improved management and treatment of livestock waste, that have benefits for animals, humans and the environment. This new thinking is not, however, a different type of silver bullet and the barriers between disciplines, institutions and the public private sector in adopting this approach remain considerable.

But what about convergence between the public and private sectors? Have there been changes in parallel to those described above? The question raised by the title of the conference, 'how can private and public research work together to reduce poverty?'... is almost a non-sequitur. Most definitions of poverty would include the inability to buy the products of private research or at least not have access to them. By restricting the following discussion to livestock vaccines and poor livestock keepers (and not consumers), that is certainly the case. Poor livestock keepers have no money to buy vaccines, no place to buy them, little knowledge of why they are needed and no economic incentives to seek them out.

In the animal health domain there has also been a convergence of approaches, or at least shared understanding that both the private and public sectors are needed to deliver good animal health care. The recent report from the World Bank, 'Minding the Stock' (World Bank 2009) is in part a response to the FAO report whose somewhat apocalyptic title 'Livestock's Long Shadow' (Steinfeld *et al.* 2006) betrayed its contents that included very positive recommendations and recognised the importance of livestock in the health of the global population and the global economy. 'Minding the Stock' dissects the necessities of private and public sector involvement along the long chain from vaccine discovery to providing technical and policy support required for vaccines to be effective and profitable. It also teases out the very complex private and public-good components of livestock production, livestock disease and disease control.

That report concludes that vaccination for livestock disease and for zoonotic disease (the livestock diseases that can and do infected

humans) is a high priority for public-sector investment.

Building on that report, in this paper I will briefly describe two broad approaches to bringing the benefits of private-sector research on vaccines closer to the poor. One approach is to stimulate supply and the other to stimulate demand.

The problem

The problem of inadequate development, supply and effective use of vaccines for and by poor livestock keepers can be summarised with these examples:

- For some diseases effective vaccines have not been developed. There is no readily available vaccine for parasitic ticks or for the many diseases transmitted by ticks such as East Coast fever.
- Some vaccines are not a good biological fit: the wrong strains of organisms are used to produce vaccines that have limited efficacy in the field where different strains are causing disease. Many viral disease such as Gumboro or Classical Swine fever fall into this category. In many cases good diagnostic capacity is require to match the vaccine to the disease organism and this has been well developed for FMD and, more recently, for influenza viruses.
- Some vaccines can't reach the user because of storage and transport requirements. The classic example of this is Newcastle Disease for which fully effective vaccines exist but the 'cold chains' to deliver them are not reliable.
- The packaging, pricing and means of delivery do not match smallholder skills, scale and available technical support. The concept of vaccination in embedded in the education systems of most developed countries from the earliest years. Where such schooling is absent, understanding of the specificity, application and benefits of vaccines is also missing.

Any list of the so-called 'neglected diseases' of importance to the poor is substantial. In some cases, as noted above, vaccines are available but can't be delivered, in others the research into vaccine development has simply failed to come up with an answer. The biological difficulties of developing vaccines against animal diseases such as East Coast fever are as complex as those to develop a vaccine for human malaria; research which has attracted greater investment by several orders of magnitude. The priority list developed by GALVmed[10] is: Newcastle Disease, African and Classical Swine fever, porcine cysticercosis, pox and Peste des Petits Ruminants in sheep and goats, and Rift Valley fever, contagious bovine pleuropneumonis, haemorrhagic septicaemia , East Coast fever and trypanosomosis in cattle.

More controversially, there may also be a conflict of interest within companies that, for example, sell chemicals that kill ticks and that produce reliable profits. Why bother with a vaccine that may be cheaper and more effective, but is less profitable?

The public-sector response

In the absence of key products, effective delivery pathways and genuine demand from end-users, how has the public sector responded? The response has been very mixed with a whole variety of initiatives which may, in some cases, have made matters worse. The example of the Queensland tick fever vaccine is a triumph of public-sector research and commitment to the industry. Since the pioneering publicly-funded research in the early twentieth century, millions of doses of whole-blood vaccine have been delivered to cattle producers in northern Australia: partly paid by the consumer and partly by the state government. But such successes are few and far between. The development of a thermostable vaccine against Newcastle Disease, again developed largely by Australian researchers, is just one of many examples where first class research has led to a potentially useful product that has been taken up in a few countries but largely ignored by the private sector in the countries of Africa and Asia where it is most needed[11].

[10] http://www.galvmed.org

[11] The master seed for this vaccine is maintained by the University of Queensland with support from ACIAR and has been distributed to 11 countries for research and development.

One public-sector response has been to subsidise vaccine manufacture, subsidies which in many cases cannot be sustained and have resulted in the production of low-quality vaccines. National policy sometimes insists that these vaccines are used in preference to imported higher-quality products. National pride, independence and the genuine and imagined fear of exploitation from commercial companies are complicating factors.

Other responses include the subsidisation of vaccine purchase, making the products cheaper or even free, and the support for the delivery of vaccines in vaccination programs, 'campaigns' as part of a 'war against disease' in which the end-user, the poor livestock keeper, has only a hazy notion of the specific disease agents and the nature of vaccines. Publicly-funded research on vaccines often makes great progress until it hits the brick wall of commercialisation. There is limited support for such research on animal diseases that mostly affect the poor (Perry *et al.* 2002) and that have limited potential in conventional markets. Since some individual benefits would accrue for these diseases, a mixed private–public-good approach is justified. Examples of such diseases might include the Peste de Petit Ruminants and African Swine fever. A more extensive list is provided by the International Livestock Research Institute (ILRI)[12], which has a leading role in identifying research required to control these diseases.

New approach 1: New products from new partnerships

In recent years there has been an intensive effort to design new ways to deliver new livestock vaccines and other veterinary drugs and diagnostics. The Global Alliance for Livestock Veterinary Medicines (GALVmed) is a not-for-profit global alliance of public, private and government partners that has partly modelled itself on the Global Alliance for Vaccines and Immunisation which has similar aims for human medicine. In essence these alliances take the approach that working together, alliance members achieve objectives that no single agency or group could achieve (Fig. 1).

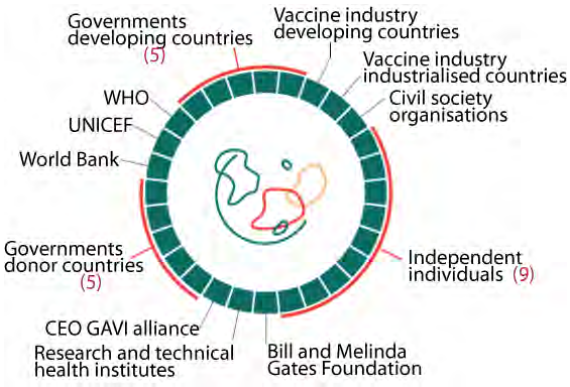

Figure 1. New alliances to create and supply new and accessible vaccines. This graphic is used by the Global Alliance for Vaccination and Immunisation (GAVI) to demonstrate the complexity of public and private stakeholder engagement.

The principle of 'mutual benefit' is paramount. GALVmed seeks to:

- accelerate access to existing underused vaccines
- strengthen health and immunisation systems in countries
- introduce innovative new immunisation technology, including vaccines.

Implicit in these objectives is that creating and supplying a vaccine is not the same as having a effective vaccination program. Good vaccines need to be delivered in good condition, administrated by adequately trained people to livestock which have an immune system in good enough shape to respond.

One of the lessons from the GALVmed experience is that each disease requires a different approach and that these processes in themselves have required substantial research and evaluation. Each disease has its own biology, creates distinct production problems and has a unique set of institutions responsible for prevention and control.

Some lessons that have emerged from the GALVmed experience and from other public–private partnerships in agricultural research include that success depends on:

- having a champion with passion for a particular product or disease
- the need to build on earlier relationships, creating social capital among individuals and

[12]http://www.ilri.org

institutions with a view to long-term partnership

- the law has no place bringing partners to the table but a poor legal framework can undermine the partnership
- the partnership needs to be adaptable and flexible. As understanding grows the game changes, and by its nature research and marketing requires many changes along the way.

New approach 2: Incentives and market access

These new alliances (GALVmed and GAVI) are focused on the supply side of the equation. But what about demand? What constitutes genuine demand, that is willingness to pay among large numbers of smallholders who traditionally have operated low-input or no-input systems? Based on experience across many countries there is very little demand even, for example, for the simplest deworming treatment that on the basis of good trials and a scientific perspective, provides large benefits for minimum cost.

In Laos, one of the poorest countries in Asia with a heavy dependence on smallholder livestock production, there has been a long-term program of applied research that has, among many benefits, created independent entrepreneurs[13] who purchase vaccines and other products wholesale and sell retail to smallholders who pay the full price for materials and services.

How has this transition to a private sector approach worked? The essential precondition has been the transformation of smallholder production from purely subsistence and asset-accumulation to a source of regular income. In this example the transformation was generated by identifying the appropriate entry point with smallholders: the saving of labour by growing forage, which in turn has improved the quantity and quality of cattle being sold to market. These smallholders now see a strong relationship between animal health investments, including deworming and vaccination, and improved prices for their cattle, and are now part of an expanding smallholder-based cattle sector.

[13] Small-scale Agro-enterprise Development in the Uplands of Lao PDR and Vietnam (SADU) is a project funded by the Swiss Agency for Development Cooperation and implemented in Laos by the International Centre for Tropical Agriculture (CIAT) and the Lao Government.

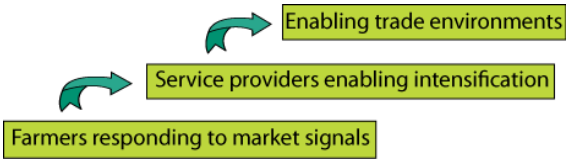

Figure 2. Bringing poor livestock keepers closer to markets: creating incentives and demand. Animal health service providers in Laos have built small businesses based on strengthened links between producers and livestock markets that in turn have created incentives for producers to invest in vaccination and create a business opportunity for animal health services.

The sequence is shown in the simple diagram (Fig. 2) which describes the response to market signals that generates capacity to pay for animal health services that in turn improves cattle health and has a spillover effect to other species. While driven by investment in cattle production, wider benefits accrue by the vaccination of poultry and pigs against other viral diseases.

These steps may seem obvious in retrospect (and therefore tempting to replicate in other systems) but were impossible to predict. The key was to seek understanding of the smallholder livelihood system as a whole and to work in a participatory fashion with farmers, the commercial sector and all public and private stakeholders.

Conclusion

These two new approaches have the capacity to bring new and better vaccines with the reach and affordability of poor livestock keepers. Bringing the private and public sectors more closely together requires improved supply of, and genuine demand for, appropriate vaccines. The scales are different, the domains are different, the skills required by participants are different, but both are essential.

In conclusion I would like to personalise these approaches by giving two examples. Both are hypothetical, but all researchers working in animal health in developing countries would be able to provide real examples. The first is of a young Asian researcher embarking on a career to develop vaccines for diseases in her own country only to see its production and use thwarted by lack of commercial interest or (in the view of the scientists in some cases) commercial sabotage. She is not looking for sympathy: she can feed her family,

but there is an element of tragedy in that wasted talent and effort.

The second example is the young mother with malnourished children in East Africa, Laos or Cambodia whose community may be affected by HIV/AIDS, who plans to rely on selling eggs and chickens to feed her family but who, unless she can access the right vaccine, will regularly lose half her flock to Newcastle Disease. That tragedy is real. It is incumbent on all of us working in the public and private sector to break down the barriers that allow such tragedies to occur.

Acknowledgments

I would like to thank Patti Kristjanson, Vish Nene and Gabrielle Persley (ILRI) for discussions on vaccines and diagnostics, Alison Wilson (CIAT) for background on animal health providers in Laos, Les Baxter (ACIAR) for his insights into private–public partnerships and Mike Nunn (DAFF) for continuing to share information and provoke discussion on these issues among the Australian research and development community.

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Agricultural Machinery: Problems and Potential

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Mechanisation of agriculture is fundamental to reducing poverty and improving lifestyle and food security in the developing world. Large populations are escaping subsistence agriculture, and there is a broad consensus that conservation agriculture (CA) is the only sustainable approach to cropping. Equipment for CA could be a major focus of R&D activity by the global farm machinery industry, but this is not happening.

Land preparation, seeding and harvesting units are the machine tools of agriculture, and must fit production systems. Tillage might be unnecessary, but tractor tillage-based systems have been the basis of the farm machinery industry. Conservation agriculture still lacks seeding equipment that is effective over a broad range of conditions, and machine-width variability of soil and residues is a fundamental problem.

Precision guidance and compatibility with permanent raised-bed and controlled-traffic cropping systems should represent major opportunities, but are not attractive commercial R&D investment propositions for the farm machinery industry. While industry and farmers will enjoy significant benefits from the adoption of CA, the community will be the major single beneficiary, via the reduced environmental footprint of a crop production system which is essential for food security.

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Introduction

Release from subsistence agriculture has led to a better life for most people, and the mechanisation of agriculture has been a key element in this process. Mechanisation can involve simple devices to improve the effectiveness of muscle power, but more commonly entails the use of internal combustion engines.

The continuous power output of most human beings is less than 0.1 kW, so for tasks where output is directly proportional to power, a person's output can be increased by a factor of ~10, ~100 or ~1000 respectively, if they are controlling an animal, a small power tiller or a medium-sized tractor. Output is clearly proportional to power for tasks like tillage, so available power in kilowatts per hectare was a reasonable index of agricultural development when tillage was a critical operation.

Mechanisation has been inextricably linked to increased power levels, and this was the basis for a prosperous and expanding farm machinery industry until 25 years ago in the developed world. The same process is occurring now in the developing world, where many people see the benefits of emulating this model, where mechanisation appears to speed up traditional practices and the popular television image of Western agriculture is still a large tractor and plough.

It is useful to list the traditional functions of tillage, which effectively summarise the advantage of conventional systems from a farm machinery industry perspective. Tillage systems ensure the use of:

- a standard base unit (the tractor, designed for drawbar tillage) for most tasks
- a small number of standard attachments (ploughs, cultivators, etc.) for land preparation
- a limited number of simple and standard items of seeding equipment.

Simple seeding equipment is possible only because tillage provides a fine, level unobstructed field surface, a real advantage for organisations that want to supply a full set of reliable and efficient equipment for all aspects of crop production. Tillage-based systems still dominate the thinking of most farmers in cool humid areas of northern Europe and in horticultural production, worldwide.

Tillage is demonstrably unsustainable and unnecessary, but its damaging consequences are much more obvious in erosion-prone environments. In these areas the principles of conservation agriculture (CA) (permanent soil cover, minimum soil disturbance, rotation) have been widely accepted by the scientific and farm advisory community. Farmers in erosion-prone areas also understand the sustainability benefits of CA, but the practicalities of seeding without prior tillage present a major challenge.

Conservation agriculture reduces the need for power for tillage, so hand-operated systems (dibble seeders and knapsacks sprayers) and attachments for animal-drawn equipment might be viable in some environments. Most attention has nevertheless focused on engine-powered equipment.

Wide adoption of CA depends on the availability of appropriate equipment, and local champions play a major role in encouraging adoption. Machinery manufacturers have dealer networks with the motivation and ability to champion adoption, so are well placed to play an important role in this process (the importance of which was demonstrated in the adoption of laser levelling, by J.F. Rickman, IRRI, Maputo Mozambique, pers. comm., 2009). If major manufacturers saw CA as a significant opportunity, adoption would be much more rapid.

Commercial organisations are driven by markets, and from the manufacturer's perspective CA reduces the market for tractor power, eliminates the market for tillage, and complicates the market for seeding equipment. Machinery manufacturers recognise that their prosperity ultimately depends on farmers' prosperity, and have modified products to meet the new demands of CA, but enthusiasm is limited for a system that will damage much of their current market.

R&D investment in CA equipment is clearly needed. Development of a new, universally applicable system for CA seeding would be a major advance, but dramatic breakthroughs are not expected by those familiar with the topic. Disincentives to commercial R&D investment include the difficulty of effective IP protection on agricultural equipment, and the fact that improvements in CA seeding are unlikely to be dependent on machinery innovation alone.

In CA, the machine × system interaction is paramount, so effective machinery R&D must work in tandem with agricultural system R&D. Discussion of current issues is the starting point for speculation about R&D opportunities for CA equipment. Consideration of the beneficiaries of such development suggests the appropriate funding sources for such work.

CA machinery — current issues

Weed control is different in the absence of tillage, but most problems can be solved by a combination of agronomic and herbicide measures. Weed management generally becomes easier with less soil disturbance to stimulate germination, so the major mechanisation issue of CA is generally acknowledged to be seeding.

Without prior tillage, CA seeders must prepare a suitable environment for the seed, then place, cover and firm it in the soil in a single pass. Major challenges include effective control of placement depth beneath uneven surfaces with varying levels of soil compaction, and handling (avoiding, moving or cutting through) surface residue. Fertiliser placement at seeding further complicates the issue.

Researchers and development projects often provide the lead, but most commercial development has been carried out by individuals or small

groups on small budgets, observing field operations with several generations of prototype, modifying, improving and retesting. Perhaps this is why most commercial CA no-till seeding units have been developed by small–medium-sized companies, and their success has occurred within limited geographical areas.

The defining characteristic of CA seeding is the complex set of interactions between seeding machine components (residue handling, seed and fertiliser placement control, covering, firming), and elements of the operating environment (soil and residues — both highly variable and highly moisture-dependent). Specifying uniform terminology for the components and describing some general characteristics of this interaction is itself a substantial task (Murray *et al.* 2006).

Seeding involves the placement of seed and fertiliser (perhaps 10 and 20 g m^{-2} respectively), effectively spaced at uniform depth (perhaps 5 cm), and no-till seeders based on tines, disks and dibblers have all shown promise in some conditions. The seed placement unit or 'opener' is the critical component. As a broad generalisation, tines cause excessive soil disturbance, disks need excessive weight for penetration and dibblers are too complex. No one opener type has proved successful under all conditions.

When soils have been managed in CA for some time they are usually softer after harvest (except for those areas wheeled by the harvester). In principle at least, the power required for no-till seeding in soft soil is small, so CA is particularly appropriate for the developing world. There are many examples of relatively small, light-weight CA seeders, usually based on tine-type openers. Individual opener depth control is unnecessary in units of small width, but residue chopping is sometimes necessary to reduce residue length and prevent blockages. Light surface tillage is sometimes used for the same purpose.

Australian CA equipment is generally built for extensive agriculture, so machine widths are large. In contrast to the light units of the developing world, most successful no-till seeders in Australia are very heavy (Ashworth *et al.* 2010). This is partly a reflection of the trend to use disk openers to minimise soil and residue disturbance, but something appears to be wrong when equipment for no-till CA is stronger and heavier than the chisel ploughs it replaced.

The underlying problem is one of variability in soil conditions within one machine width. No-till seeders units must be able to work successfully in soil which is soft and friable, but they must work equally well in that 20% of machine width where the soil is hard, having been wheeled by a >20-t harvester, in the 5% of width wheeled by sprayers and handling equipment, or in the 20–30% wheeled by the tractor and seed handling and distribution system.

Hard soil can occur at any point across the width of the machine, so every opener unit must carry adequate weight to penetrate the hardest soil. Where the weight is not needed for penetration (across 40–60% of machine width) it must be carried by opener depth control wheels. These small wheels can require a draft force of 20–30% of weight to roll over soft soil, demanding great frame strength and tractive power.

Residue handling is the other major issue for no-till seeders. In very heavy residues (maize or rice) there might sometimes be no alternative to the use of power to chop, distribute or otherwise encourage residue to pass the openers without obstruction (Blackwell 2002). In many cereal crops, serious problems occur only when the harvester concentrates residue. If residue passing through the harvester is distributed evenly, the remaining residue, anchored and standing in rows, rarely presents any obstruction to an opener passing between the rows. The exception is where residue has been flattened during harvesting.

Machine-width soil variability is the product of wheel impacts. Residue issues are a consequence of concentration or re-orientation during harvest, at least for an opener seeding in the interrow. The fundamental point is that most of the problems of no-till seeding are not inherent in the situation: they are artefacts of management — specifically they are the product of imprecise machinery operations.

CA equipment — opportunities

The farm machinery industry will find new opportunities in improved harvesting systems, from agronomic developments in rice production, and from increasing mechanisation levels in vegetable production. In most crop production systems, however, the major opportunities will be those related to some aspect of precision. This will include the mapping and response to macro-scale variability — the focus of current 'precision

agriculture' — and the use of weed-sensing and similar technologies. Much greater opportunities will come from the response to machine-scale variability.

Machine-scale soil variability can be managed by using precise guidance to restrict the wheels of all cropping equipment to permanent traffic lanes. With precise guidance, most crops can be interrow seeded, avoiding most residue handling problems. With this level of precision, weed management can be improved by restricting herbicide application to the row or interrow zone where it is needed, reducing off-target application. Productivity and sustainability improve substantially when a large proportion of the field area is uncompromised by wheel compaction effects in permanent raised bed (Roth *et al.* 2005) or controlled traffic farming (Tullberg *et al.* 2007).

Some benefits of precision will be available only in sophisticated systems, but a high level of precision can be achieved with permanent raised beds, particularly if machinery is designed for this purpose. In these low-cost systems permanent beds are defined by traffic lanes—permanent wheel ruts in furrows. Limited soil movement for bed rejuvenation can provide some weed control, which can be useful in environments where herbicide knowledge is poor. With greater investment, precision GPS guidance can be used to achieve the same advantages 'on the flat' in controlled-traffic farming. Permanent raised beds and controlled traffic both restrict all heavy load-bearing wheels to narrow permanent traffic lanes, where compaction and surface hardness make transport and traction operations more efficient.

Guidance precision is already adequate in small-scale mechanised CA, where the crop, residue and machine component can be seen by the operator in permanent bed systems. These systems allow low-cost mechanisation using single-axle power tillers modified for no-till CA seeding (J. Esdaile, No-till agriculture consultant, Tamworth, pers. comm., 2009). Sophisticated GPS guidance becomes essential with large-scale CA, but 2-cm precision guidance (autosteer) is already available at a cost <15% of tractor price. With GPS technology already incorporated in some mobile phones, low-cost precision guidance can be expected in the next few years, and could be readily incorporated into small-scale equipment.

A recommendation that we should deliberately drive heavy vehicles over all our cropping areas before planting would be laughable — until we note this is a close approximation of current practice. The impact is most obvious with large tractors and harvesters, but it also occurs with small machines. The problem has arisen because compatibility between machine track, tyre and working widths has been seen as 'too difficult'— but it is simply an issue of products currently on the market.

The farm machinery industry can make a major contribution to CA systems by producing equipment that is compatible with permanent raised-bed and controlled-traffic systems. For most practical purposes this is a matter of track width adjustability, narrower tyre options and a range of working widths. Agreed sets of standard track, tyre and operating widths would be a major advantage. This substitution of precise crop management for overall tillage would represent a radical change of focus for an industry organised to produce equipment often characterised by its size and weight.

CA equipment R&D — beneficiaries

Farmers

The steady accumulation of economic and production data leaves little room for doubt that farmers will be beneficiaries of a change to CA. It is nevertheless true that adoption is not a straightforward process, and farmers have sometimes been defeated by the difficulties of seeding or weed control in a new system. One tale of economic woe is always repeated many more times than a dozen success stories, so CA adoption rates are still too low. Too few farmers see themselves as beneficiaries of CA, particularly in the developing world.

Manufacturers

Manufacturers respond to markets, and current requirements for CA equipment — largely seeders — are too imprecise and uncertain for the major manufacturers. These markets are attractive to small-scale regional manufacturers, who produce most currently available CA seeders, but the issues of precision and compatibility with permanent traffic lanes are related to tractors and harvesters — products of the major manufacturers.

The large farm machinery companies are working to ensure that their products are readily compatible with precision guidance, but for a global

manufacturer, the issues of track, tyre and operating width compatibility are extremely complex and influenced by factors such as road traffic regulations. The bigger companies have considered the issue, but change has been limited to acceptance of local modifications of their products. Manufacturers will not move without a market, and farmers cannot demonstrate a market until equipment is available — the traditional chicken and egg situation.

Community and environment

No-till CA — particularly when combined with permanent raised bed or controlled-traffic farming — will reduce the environmental footprint of agriculture, and improve food security. In the most general terms:

- Stopping tillage reduces energy requirements, and combining this with controlled traffic reduces tractor power and cropping fuel requirements dramatically. Less energy means less atmospheric pollution.
- Stopping tillage will reduce runoff and erosion. Combining this with controlled traffic produces a much larger effect. Less water running off cropped soil means less erosion, sediment, nutrients and pesticides in watercourses and water supplies.
- Controlled traffic no-till greatly improves soil porosity and internal drainage, which should substantially reduce soil emissions of nitrous oxide (a potent greenhouse gas).
- Greater precision improves the spatial placement of fertiliser and pesticides. Working from permanent traffic lanes in controlled-traffic or raised-bed systems also enhances farmers' capacity to apply fertiliser and pesticides at the optimum time to match crop requirements. The outcome is reduced loss and environmental pollution.

The overall environmental impact of different mechanised cropping systems is illustrated in Figure 1 in terms of greenhouse gas emissions due to energy in fuel, herbicides and fertilisers, and the effect on soil emissions. The magnitude of some of these effects might be arguable, but there would be little dispute about the overall trend: as we disturb the soil less by tillage and compaction, we improve productivity and the use efficiency for all inputs, and reduce the environmental footprint.

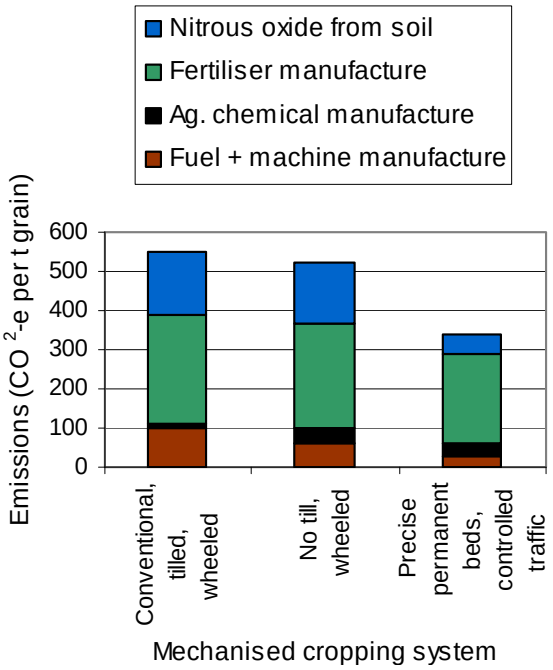

Figure 1. Carbon dioxide equivalent emissions from conventional tillage, simple no-till and precise no-till cropping systems

Emissions illustrated here are broadly representative of those from rainfed grain production, but they vary greatly with crop, soil, fertiliser regime and system. Life-cycle emissions from fuel, agricultural chemical and fertiliser use are energy related, and the comparisons are uncontroversial. System impacts on soil emissions have been inferred from research in other environments (Tullberg 2009).

Conclusion

The absence of effective CA equipment is an important factor slowing adoption of a technology of great significance to sustainable development, food security and the relief of poverty in a number of regions. Seeding residue-covered, uneven soil surfaces is the major issue.

Low-cost, locally driven development by regional manufacturers, often cooperating with research projects, has provided most CA equipment. These small organisations cannot address important tractor and harvester-related issues of compatibility with permanent traffic lanes and precise guidance.

Farmers are beneficiaries of the change to CA, but the issues of system change are real when they

need to re-equip in a situation of uncertainty about equipment types and suitability.

Major farm machinery manufacturers are reluctant to invest in CA equipment R&D when they are unlikely to capture the benefits of any resultant innovation.

The community will be the major beneficiary of CA equipment research, largely as a consequence of the reduced environmental footprint of crop production activities that are necessary for food security. Government or government-mediated funding via systems such as the Clean Development Mechanism or its successors appears to be the only way forward for research and development on the basic and essential issues of mechanisation for CA.

This is not a very satisfying outcome for a conference concerned with private enterprise R&D opportunities and poverty reduction. In view of the limited farm machinery R&D resources now within the public domain in Australia, such research could well be the objective of innovative public–private partnerships.

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The Power of Partnerships: A Private-sector Perspective

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The world food crisis, exacerbated by accelerating climate change and the global financial crisis, requires that agricultural scientists solve ever more complex problems. Public–private partnerships will play a more critical role in developing agricultural technologies for developing nations to improve farm productivity and alleviate global hunger. In order to make public–private partnerships work, we must move from the 'sector mentality' and focus on combinatorial solutions resolving the most pressing issues. Critical observations from past and current efforts are helpful in designing new relationships and approaches towards driving innovation. Aggressively supporting the development of mutually-beneficial partnerships with a novel mindset will ensure that we fully exploit the tremendous potential that modern technologies promise.

The power of partnerships

The phrase 'Power of Partnerships' itself is widely used. A Google™ or Wikipedia search on the phrase will return hundreds, if not thousands, of entries where the concept is used to address issues in every imaginable industry and situation.

DR WILLIAM NIEBUR, DuPont Vice President for Crop Genetics Research and Development at Pioneer Hi-Bred International Inc., drives worldwide crop genetics research strategies to create new value for Pioneer seed and agricultural value-chain customers through advanced plant genetics. He has been instrumental in integrating proprietary technologies into DuPont plant genetics product development. He holds Bachelor of Science and Master of Science degrees from Iowa State University and earned his doctorate in plant breeding and cytogenetics from the University of Minnesota. He has served as the chair of CGIAR's Private Sector Committee since September 2006.

A few common threads run through many of the search results, regardless of industry. Key words and phrases such as 'creativity,' 'leadership,' 'effectiveness,' 'addressing challenges,' 'successful,' 'innovative' and others are used to describe partnerships that have accomplished their goals.

It is well known and has been well publicised through the media and scientific conferences that the world is facing significant agricultural production challenges today and into the coming decades. These global food security challenges are becoming more complex and interconnected. The uncertainties of climate change, political unrest and the global financial crisis also have a significant impact on our ability to improve agricultural productivity.

Global food security challenges cannot be solved by any one company, government, university or research organisation. Individually, we do not have the resources, global access or talent needed to address the uncertainties of issues like the impact of climate change on crops or improving agricultural productivity during times of financial or political unrest.

As scientists, we have a moral imperative to develop sustainable and innovative solutions to ensure food security for a growing world population.

The true 'power of partnerships' for agricultural productivity today is to understand and embrace the fact that public–private partnerships are critical to global food security; key to delivering needed agricultural productivity increases amid complex global issues, and effective only if well designed and executed.

The final point — designing and executing effective partnerships — is an area that is often overlooked, but arguably of greatest importance to success. The remainder of this paper will focus on this topic.

Building effective and successful partnerships

Successful partnerships create clear accountability. They fully capture the strengths of each partner, have clear goals, inputs and timelines in place, and offer distinct benefits to all parties to ensure the sustainability of the effort.

A company like DuPont is motivated to enter a partnership when it provides the opportunity to form — with the right partners, structure and goals — a collaboration that can accomplish something the company doesn't feel it can do alone.

Effective partnerships are built by following a handful of key principles.

- Partnerships must be designed to capture the strengths of each partner. This requires moving away from a 'sector mentality' and focusing on collaborative solutions to meet the most pressing challenges. A partner's strengths can include technical capabilities, global reach, local connections or a variety of other attributes.
- Partnerships are most successful when they are specifically designed to the scope of the challenge.
- Without effective regulatory and intellectual property infrastructure around the globe, the new technologies that are essential to improving productivity cannot be introduced. And, education and training programs must be in place to deliver the next generation of plant breeders with necessary skills. This training gap is a global issue. The challenges ahead can be met only if scientists are deployed on the ground around the world. That requires trained plant breeders in every corner of the globe.

Capture strengths of each partner

The concept of sector mentality refers to anything that pigeonholes a person or organisation into responsibilities based on old stereotypes or outdated expectations. It is essential to break down silos and barriers and focus on what players are needed to accomplish a specific goal.

In many cases, this sector mentality dooms a partnership before it is even started. The simplified and fictitious example in Figure 1 shows how easy it is for private companies, academics, governments and research institutions to be working on similar projects to enhance productivity for a crop. In each case, they are investing time and resources toward a positive goal.

Each sector brings strengths, such as significant research and development investment capabilities from a private company, as well as limitations, such as a single-country focus for a government. Across the board, however, they miss tremendous opportunities to pool resources and work toward a common goal.

Figure 2 provides another look at the same example, this time removing the silos and barriers between each entity. In this version, the partnership is designed to maximise the strengths and resources of each player and has a much farther reaching and more beneficial impact.

By combining resources, these organisations can take an idea or intention, move it to innovation, to deployment and finally deliver impact.

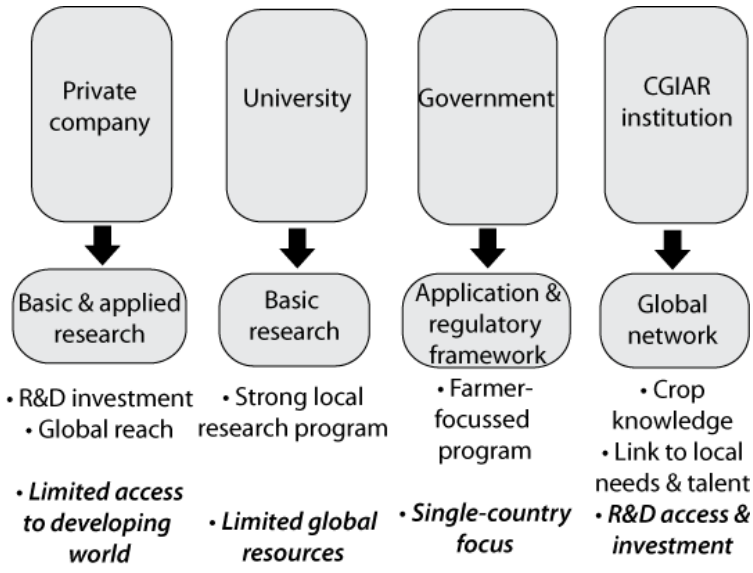

Figure 1. In isolation, institutions forego benefits of complementarity

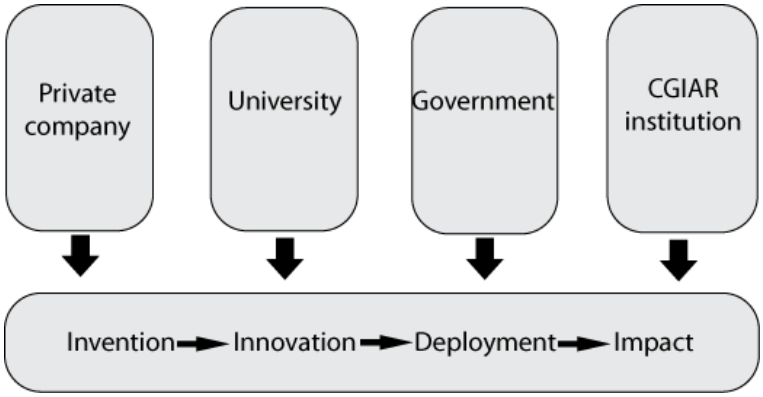

Figure 2. Progress is maximised in a cooperative environment

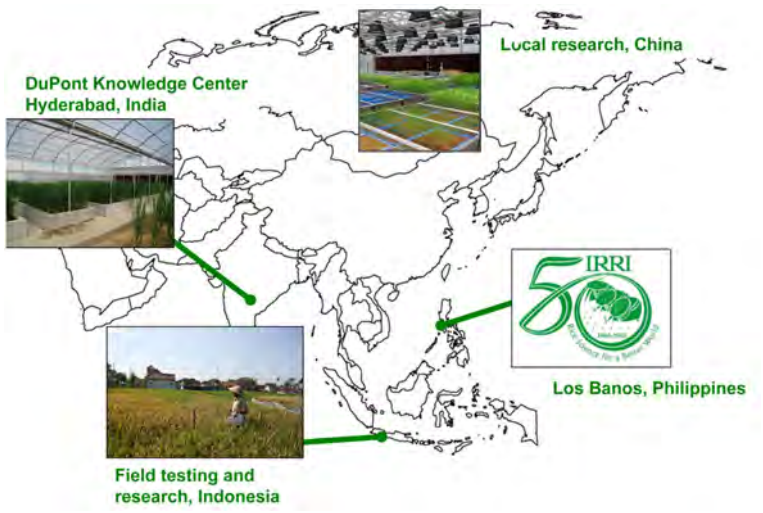

Figure 3. The DuPont–IRRI Scientific Know-how Exchange Program

It is important to note that these organisations should not strive to replace or take over the roles of the other. Each has a very important role with unmatched strengths.

A real-world example to illustrate the concept of capturing the strengths of all partners is the DuPont and International Rice Research Institute (IRRI) partnership to boost rice yields (Fig. 3). The Scientific Know-How and Exchange Program (SKEP) establishes a new model for public–private sector collaboration that can benefit rice researchers, farmers and consumers while stimulating commercial innovation. The research will be conducted on the ground in rice-growing areas such as Indonesia, in world-class research facilities in India, and at IRRI and DuPont locations in the Philippines and across Asia.

The goal of the collaboration is to increase the rate of yield gains and to boost the quality and diversity of hybrid rice. Collaborating scientists will further develop the understanding of hybrid vigour in rice and will work to develop hybrids with better resistance to brown planthopper, a key insect pest. Aspects of this work will be shared publicly and will contribute to making better advanced breeding lines and hybrids available to rice breeders and farmers in Asia. The project will complement the IRRI-led Hybrid Rice Research and Development Consortium.

This project is a great example of a partnership between world-class research organisations using local infrastructure in rice-growing locations to deliver technologies in regions where they are most needed.

Design partnership for success

Once a group of partners with complementary strengths and resources is identified, the next step is designing the partnership for success. Partnerships are most successful when designed with clear accountability and specific to the scope of the challenge.

Key aspects of a successful partnership are:

- **Profit** is often viewed as a four-letter word, especially when it is used in the same sentence as private sector. However, every partnership must be rooted in mutual growth and mutual benefit. The ultimate goal is to improve productivity and food security, but neither the private nor public sectors can do anything if the bills aren't paid first. Private companies may have desire to take on every challenge and philanthropic effort, but ultimately must deliver a return to their shareholders. That drives a company to only take on partnerships that are within its business focus and can be effectively carried out. Non-profits and research centers must also look for the benefits in a partnership. Profit may not be financial, but could also include access to top talent, new alliances or access to germplasm or other resources.

- Partners should **focus** clearly on the goals of the partnership and not allow 'mission creep' or the addition of extra tasks and activities that may detract from the primary goal.
- Each party must be committed to **transparency**, including open lines of communication and respectful working relationships.
- The word '**velocity**' describes the speed of working together on a project. If a project is the top priority for one partner and at the bottom of the to-do list for another partner, there will be serious problems in working together. All parties need to be on aligned on rate of progress.
- Prepare for the **time** commitment involved. This time commitment for partnerships goes beyond lab or field work. Effective partnerships commit appropriate levels of time and resources for planning, update meetings, communications and the like.
- Finally, the most successful partnerships happen when all the partners check their egos at the door. A little **humility** goes a long way.

The African Biofortified Sorghum Project is another example of a real-world partnership (Fig. 4). Part of the Bill and Melinda Gates Foundation Grand Challenges in Global Health program, this is an excellent example of how technology developed in the private sector would have sat unused on a shelf without a public–private partnership to put it to use.

This project primarily aims to develop a more nutritious sorghum that contains increased levels of Vitamin A, and more available iron and zinc. Pioneer scientists had developed technology for corn that could also boost the nutritional value of sorghum, but the potential African market size didn't support the technology and regulatory investment necessary. The Gates Foundation program and African Biofortified Sorghum (ABS) consortium provides the opportunity to bring technology to real life.

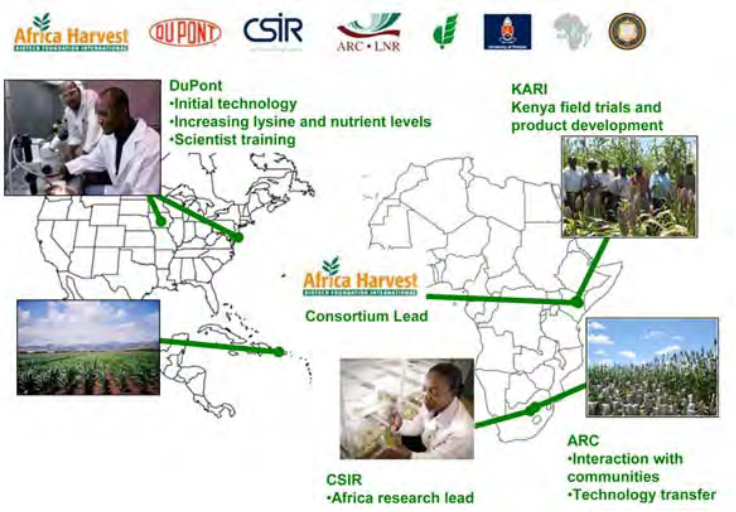

Figure 4. The African Biofortified Sorghum Project Consortium

The project includes 11 world-class research institutes or organisations and is led by the Africa Harvest Biotech Foundation. Now in its fourth year, the project is making excellent progress and is overcoming regulatory hurdles. A project of this magnitude with partners on multiple continents requires significant commitment in order to stay on track with regulatory and research timelines.

Conclusion

Partnerships between private companies and the public sector are the preferred mechanism to address many of the food security and agricultural productivity challenges in the world today. Each day, our world becomes more interconnected and the challenges we face become more complex. The optimal way to effectively address these issues and truly deliver global food security is through well-designed and executed public–private partnerships.

Staple Crops, Smallholder Farmers and Multinationals: The 'Water Efficient Maize for Africa' Project

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Doubling food production by 2050 under conditions of climate change and depleted natural resources requires increased investment and creative approaches. The Water-Efficient Maize for Africa (WEMA) project, a five-year public–private partnership begun in 2008 and led by the African Agricultural Technology Foundation (AATF), is an excellent example. Under WEMA, Monsanto, the International Maize and Wheat Improvement Center (CIMMYT), and national agricultural research systems in Kenya, Mozambique, South Africa, Tanzania and Uganda are developing, testing and disseminating drought-tolerant maize. Efforts involve both advanced, conventional breeding techniques and biotechnology tools. Transgenic drought tolerance from Monsanto and BASF is being added to elite, drought-tolerant maize lines from CIMMYT and Monsanto so that the new varieties will better withstand the increasing impacts of climate change in Africa. WEMA varieties under development have been licensed to AATF for eventual use by local, qualified seed producers and made available to them royalty-free.

The project reflects both Monsanto and CIMMYT's goals of putting advanced technology within reach of smallholder farmers in developing countries. In this pioneering effort, important challenges have arisen around project governance, contrasts in institutional culture, managing risk, intellectual property and external communications. More difficulties loom in the areas of regulatory approval, contracting, delivery and stewardship. Addressing these issues demands determination, creativity and good faith of all parties. WEMA is proving a valuable learning experience for participants and, hopefully, a model for multi-sectoral alliances that focus on crucial development aims.

Introduction

Doubling food production by 2050 under conditions of climate change and depleted natural resources requires increased investment and creative approaches. The public and private sectors have an increasing responsibility to work together to help smallholder farmers adapt to climate change. Agriculture has served as an engine of economic growth and as a major force for poverty reduction in many countries. But in sub-Saharan Africa (SSA), yields and poverty have changed little in recent decades (World Bank 2007). In most countries of this region, low agricultural growth, rapid population growth, weak foreign exchange earnings and high transaction costs in linking domestic and international markets all combine to threaten household food security. Chemical fertiliser use has expanded in most of the developing world, but not in SSA.

The risks of agriculture without choice: human and national deprivation

Sub-Saharan Africa is the only region in the world where both the number and the proportion of malnourished children is expected to increase over the next decade (Rosegrant *et al.* 2001). Over 60% of all people in SSA depend on agriculture for food and income. Most are members of very poor families with smallholder mixed farming systems in drought-prone areas with little access to inputs, service providers and produce markets, education and infrastructure, and an average annual per capita income of only US$165 (FAO 2006; World Bank 2006). The average yield for maize region-wide is 1.2 tons per hectare, but in drought-affected years or on widespread, infertile areas, farmers obtain less. Poor harvests mean that households often run short of last year's maize before the next crop is ready for harvest, that school fees and health costs cannot be paid, and that no monies are available to purchase inputs for next year's crop.

Recurring droughts provide a continuous challenge to farming in Africa. A close relationship between maize yields and rainfall can be observed for eastern and southern Africa (Heisey and Edmeades *et al.* 1999). A terrible drought in 2002–2003 resulted in a food deficit of 3.3 million tons, with an estimated 14 million people at risk of starvation. A severe drought in the Horn of Africa as recently as 2008–2009 led the World Food Program to appeal for more than US$230 million to provide emergency food assistance to 3.8 million Kenyans (WFP 2009). To make matters worse, the predictions of climate change suggest that increased variability of rainfall and temperatures will significantly affect maize grain outputs (Jones and Thornton 2009). Even under current circumstances, many farmers living in drought-prone areas are highly vulnerable and would benefit from crop varieties that are higher-yielding in good and bad years, and produce sufficient food in a much greater number of drought years. Stabilising and increasing productivity in the face of recurring droughts also has significant importance for crop diversification, soil fertility and income generation, as farmers typically respond to the recurring threat of drought by planting more maize than needed in an average year. Drought-tolerant maize varieties would provide them with food security on a smaller land area, freeing up land and labor for soil fertility-enhancing legumes, vitamin-rich vegetables and cash crops.

The importance of maize

Maize is the primary grain crop grown for human consumption in sub-Saharan Africa, forming a significant part of the diet (Bänziger and Diallo 2000). Over 650 million people consume on average 43 kg of maize per year (a 35% increase since 1960), reaching 85–140 kg in Kenya, Lesotho, Malawi, South Africa, Zambia and Zimbabwe (FAO 2006). Among different income groups, maize is a relatively more important source of both calories and protein for the poorer proportion of consumers (Byerlee and Eicher 1997), including HIV/AIDS-affected families who cannot afford more expensive foods such as bread, milk or meat. For a smallholder farm family, harvesting sufficient maize despite drought is core to family food and income security: it determines whether children eat twice or more a day and whether fees can be paid for them to attend school; it enables families to take care of their basic needs and to acquire assets as a reserve for harsher times. More than 50% of all SSA countries assign over 50% of their cereal area to maize. Maize production has strategic importance for food security and the socioeconomic stability of countries and sub-regions.

Many constraints adversely affect maize yields, including poor soils, weed and insect pressure and drought. In addition to its destructive effects on the food security and household economies of smallholders, drought is particularly damaging because it discourages farmers from investing in best management practices, including quality

hybrid seed and fertiliser, for fear of losing their investment. Because over 90% of SSA cropland is rainfed and likely to remain so, identifying ways to mitigate drought risk, stabilise yields and encourage investment in best management practices is fundamental to enable a 'Green Revolution' in Africa.

Drought-tolerant varieties: a reality

In collaboration with a wide range of public and private partners, CIMMYT has achieved significant successes in the development of drought-tolerant maize varieties (Bolaños and Edmeades 1996; Edmeades *et al.* 1999; Bänziger *et al.* 2006). The first suite of drought-tolerant open-pollinated and hybrid varieties adapted to SSA agro-ecologies were released in 1999, and through collaboration with a wide range of public and private partners seed production has been scaled up to plant over one million hectares every year with certified seed from the formal sector (Van Eckert *et al.* 2006). Through collaboration with the International Institute of Tropical Agriculture (IITA), under the Drought-Tolerant Maize for Africa (DTMA) project[14], equivalent drought breeding methods have been applied to maize germplasm adapted to WCA countries, and West African national agricultural research systems are now annually providing 300 tons of breeder seed to community-based seed production schemes for diffusion to farmers.

Research by Monsanto on drought-tolerant maize

Drought-tolerant varieties developed to date by CIMMYT are benefiting farmers, but there is more that can be done. Monsanto is also working on drought tolerance in maize for commercialisation in the United States using a combination of conventional breeding, molecular breeding and biotechnology techniques. Their research targets parameters associated with yield stability under drought conditions such as improved harvest index and kernel number. Monsanto evaluates hundreds of genes each year in its biotechnology pipeline. Its current lead drought tolerance event[15] has been tested extensively and reached the pre-commercialisation stage. Data demonstrating the food and feed safety of this event have been submitted to numerous regulatory agencies around the world and are currently under review.

Monsanto invests about one billion USD in R&D each year. CIMMYT invests about USD 40 million in R&D each year. It thus seems clear that CIMMYT and other public research organisations should partner with the private sector to bring products of private investment to developing world farmers who cannot be reached through commercial market channels.

Water-efficient maize for Africa

The Water-Efficient Maize for Africa (WEMA) project, a five-year public–private partnership initiated in 2008 and led by the African Agricultural Technology Foundation (AATF), is an excellent example of a unique approach to help African farmers respond to climate change. Under the project, Monsanto, CIMMYT and national agricultural research systems in Kenya, Mozambique, South Africa, Tanzania and Uganda are developing, testing and disseminating drought-tolerant white maize. In the WEMA partnership, AATF is contributing its leadership, unique experience in public–private partnerships, and technology stewardship. CIMMYT is providing high-yielding maize varieties that are adapted to African conditions, expertise in conventional breeding and testing for drought tolerance, and its good name and the trust of partners in the region, including national research programs and local seed companies. Monsanto is providing proprietary germplasm from its global germplasm pools to introduce novel sources of drought tolerance to African germplasm, its conventional and molecular breeding platforms, drought-tolerance transgenes developed in collaboration with BASF, and its expertise in these tools. These contributions are being provided without royalty to the WEMA project. The national agricultural research

[14] Formally launched in 2007, the DTMA (http://dtma.cimmyt.org/) is jointly implemented by CIMMYT and IITA and funded by the Bill and Melinda Gates Foundation and the Howard G. Buffett Foundation. Its activities build on nearly two decades of collaborative research beginning in Mexico to develop drought-tolerant maize and a history of generous support from donors including the United Nations Development Programme (UNDP), the Swiss Agency for Development and Cooperation (SDC), the German Federal Ministry for Economic Cooperation and Development (BMZ), the International Fund for Agricultural Development (IFAD) and the Eiselen Foundation. Maize varieties from the DTMA provided yields as much as 30% higher than those of other widely-sown varieties in the severe drought that hit eastern Africa during 2009.

[15] An 'event' refers to a specific instance of a specific transgene that was successfully introduced into the plant genome at a specific location and that is 'expressed' in an experimental maize plant.

systems participating in the project are contributing their expertise in field testing and play a key role in the development of the WEMA varieties, in seed multiplication and in distribution.

The partners estimate that the maize products developed over the next ten years could increase yields by 20–35% under moderate drought compared to current varieties. This increase would translate into about two million additional tons of food during drought years in the participating countries, meaning 14–21 million people would have more to eat and sell. In addition, the WEMA partnership provides a unique form of capacity building, especially through the extensive scientific training underway in participating countries.

Each partner has its own reasons for joining the partnership. CIMMYT joined to capitalise on the research and development investments of Monsanto for the benefit of African farmers. The centre has developed drought tolerance to a certain level in SSA germplasm and hopes that this work will be further amplified in the WEMA partnership, with help from Monsanto's marker-assisted breeding platform and the drought-tolerance transgenes.

Monsanto joined this partnership because it believes African farmers deserve the chance to choose the same kinds of technologies and tools as farmers elsewhere. Monsanto recognises the importance of providing drought-tolerance tools to smallholder farmers in Africa as quickly as possible and believes it has a responsibility to make that technology available to African farmers who choose to use it.

Lessons learned and issues to address

The deployment of improved maize varieties in Africa will require public and private partners working to develop a functional regulatory framework and improved seed systems. Regulatory systems in Africa must be developed that allow for timely field trials, collection of data and the deployment of transgenic products. They must give confidence to the public on the safety of the products. Success will also require seed companies that have excellent quality control measures and the infrastructure and production capacity for producing hybrid seed, while managing intellectual property at the delivery end. This partnership is designed to foster the growth and viability of small and medium-scale African seed companies, promoting healthy competition in the market place and, ultimately, an affordable supply of quality seed and other inputs and services to farmers in the region.

The WEMA partnership is two years old and working towards developing and delivering drought-tolerant maize for African farmers. Over the last two years, we have learned many new things. Most importantly, we have learned that working in partnerships has its challenges and requires effective communication, both internally within the partnership and with external stakeholders. Monsanto and CIMMYT have very distinct institutional histories, cultures and expectations. Both have gained considerable experience already in working together and understanding what motivates the other.

More generally, the WEMA partners are diverse and represent the public and private sectors and several countries. All are learning to recognise and respect their differences and work towards a common goal of helping improve the lives of Africa's farmers.

Helping farmers face the future

The extensive challenges facing African farmers are expected to increase as a result of climate change. Helping farmers respond to them will require the leveraging of both public and private expertise. WEMA is an example of a partnership that does just that.

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Private Sector Partnering on Crops for the Poorest of the Poor

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has a mandate to improve the livelihoods of the poor in the semi-arid tropical (SAT) regions of Sub-Saharan Africa and Asia, which is home to 550 million poor people. Sorghum, pearl millet, chickpea, pigeonpea and groundnut are the staple food crops in the SAT, often grown on marginal lands with poor soil fertility and erratic rainfall. Dryland farmers are physically, economically and politically vulnerable and need to be empowered to enhance their income and livelihoods. Seed-based technologies (high-yielding and adapted cultivars) are the cheapest and easiest to be adopted by poor farmers, and often serve as catalysts for adoption of inputs such as fertiliser, pesticides and good crop management practices. ICRISAT partners with public- and private-sector institutions to ensure that seeds of improved varieties and hybrids are available to poor farmers at an affordable price and at the right time and place. As a public-sector institution, ICRISAT develops improved varieties and hybrid parents. Private-sector (PS) partners test, multiply and market promising hybrids through their well-established market linkages in the rural areas. ICRISAT has partnered with more than 50 seed companies in India, Indonesia, Egypt, Mexico and Brazil through a novel consortium approach to deliver its research products (improved hybrids and varieties) to poor farmers through public–private partnerships. Some PS partners, who have their own research programs, also benefit by accessing pre-release breeding material. This approach exploits complementary expertise and resources, and generates synergies between international agricultural research centres (IARCs) and the PS in development and marketing seed of improved cultivars, without compromising the global research agenda in delivering international public goods (IPGs).

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Introduction

Partnership between public-sector research institutions and private-sector companies is considered important and essential for enhancing the scale and pace of agricultural research and development (Reddy *et al.* 2001). Although public-sector research has been relevant and has contributed to enhancing crop productivity in resource-limited areas, the private sector has reportedly played a major role in resource-endowed areas and in irrigated regions (Ryan and Spencer 2001). However, Fan *et al.* (1999) have shown that returns to agricultural research are often higher in the more marginal areas, and there are complementarities to be exploited through public–private partnership research, even in low-potential areas in develop-

ing countries. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972 at Patancheru, near Hyderabad in Andhra Pradesh, India. ICRISAT's vision is to improve well-being of the poor of the semi-arid tropics, and its mission is to reduce poverty, increase agricultural productivity, enhance food and nutritional security and protect the environment of the semi-arid tropics by helping empower the poor through science with a human face and partnership-based research. ICRISAT's major mandate is genetic improvement of grain and fodder yields of sorghum, pearl millet, pigeonpea, groundnut and chickpea. The objective of this paper is to discuss the evolution of public–private partnership at ICRISAT, its impact on development and adoption of improved cultivars in India and its implications for enhancing crop production in developing countries. This case study illustrates that partnering with the private-sector seed companies does indeed benefit the poor people who grow dryland crops such as sorghum, pearl millet, pigeonpea and other legumes.

About 2.1 billion people in the world live on less than $2 a day and 880 million on less than $1 a day. About 850 million people are food-insecure due to issues of availability and access to food. The FAO's 2006 *State of Food Insecurity Report* cites agricultural growth as critical for reducing hunger (FAO 2006). Future global food security cannot be taken for granted given the scarcity of resources like land and water, and the new challenges posed by climate change. Moreover, with global food reserves at their lowest level for 30 years, food price hikes seen during 2008 are likely to continue.

Agriculture is a crucial development tool that can help achieve the Millennium Development Goal of halving the number of people living in extreme poverty and hunger by 2015. Whether as an economic activity, or a means of livelihood or a provider of environmental services, agriculture is a unique instrument for development because of its ability to work with other sectors.

Advances in agricultural research and development, including major breakthroughs in new areas of science, have significantly contributed to meeting the challenge of food and nutrition security, agricultural sustainability, production and productivity. For every $1 invested in international agricultural research, $9 worth of additional food is produced in developing countries where it is needed most. Less than 10% of public spending in developing countries goes to agriculture even though this sector commonly accounts for about half of their Gross Domestic Product, and less than 1% of public spending goes to agricultural research, which is vital to the innovation that opens new livelihood opportunities. Of that 1%, only a small proportion is invested in dryland agriculture (Dar 2008).

In developing countries, private-sector (PS) investments in agricultural research and development are concentrated in a few large countries such as Brazil and India. Traditionally, PS focused on mechanical and chemical innovations where proprietary knowledge could be easily protected. Except for hybrid seeds, the PS did not engage itself in biological technology in the past. However, with the advent of biotechnology and the broadening of the scope of intellectual property rights (IPR) into life forms, the PS is becoming a major player. In India, the Central Seed Act of 1966 had restricted the development of the PS seed industry and as a result public organisations had dominated agricultural research and seed production (Morrison *et al.* 1998). However, the enactment of new seed policy in 1988 (in India) encouraged the PS to engage in seed production and in R&D.

Public–private sector partnership and ICRISAT

Public–private–people partnerships in agricultural R&D are increasingly viewed as an effective means of conducting advanced research, commercialising new technologies and deploying new products for the benefit of resource-poor, food-insecure farmers and other marginalised groups in developing countries. Multi-level strategic partnerships mobilising science and technology for the poor lie at the heart of all ICRISAT's research, including its links with researchers based at international, regional and national organisations spread across Asia and Sub-Saharan Africa. ICRISAT is committed to strengthening the capabilities and opportunities of developing-country scientists, civil society organisations and communities. It undertakes collaborative research and provides high-quality, unbiased and timely information to everyone from policy-makers to local communities, from agriculture-related industries to research scientists. It recognises that building capacity is a two-way process. While partners benefit from ICRISAT's expertise and its

technological tools and resources, many ICRISAT research projects benefit greatly from the skills and knowledge that its research partners bring to the table. ICRISAT has taken a proactive approach to develop partnerships with private-sector companies (including profit-making state and national seed corporations), foundations and trusts to jointly deal with the main constraints to rural development through the identification of priorities and joint collaboration in key research areas (Dar 2008).

Agri-Science Park @ ICRISAT

The Agri-Science Park @ ICRISAT was started in 2003 as part of the Genome Valley Initiative of the government of Andhra Pradesh, India. Its mission is to be the 'hub' for public–private partnerships that enhance the development and commercialisation of science-generated technologies and knowledge through market mechanisms that will ultimately benefit the poorest of the poor. Among its components are:

- Agri-Business Incubator (ABI)
- Ag-biotech Innovation Center (AIC)
- Hybrid Parents Research Consortia (HPRC)
- Bioproducts Research Consortium (BRC).

In this paper, we describe the formation and implementation of the HPRC as a case-study in public–private partnership.

Hybrid Parents Research Consortia

The crop improvement program at ICRISAT and those of its partners have developed a diverse range of improved breeding lines, varieties and hybrid parents and have shared these with national programs, including the private sector. More than 650 varieties and hybrids have been released and marketed in many countries, leading to tremendous increases of production and productivity, and enhanced income to farmers.

The partners involved in crop improvement at ICRISAT include:

- national agricultural research systems (NARS)
- advanced research institutes, both in the north and south
- private-sector seed companies
- non-government organisations
- farmers' organisations and cooperatives
- farmers — both men and women.

ICRISAT's crop improvement research is supported by funds from various public and philanthropic donors. The funds are provided for producing global public goods and the outputs of this research remain in the domain of international public goods (IPGs) — accessible equally to both public research institutions and PS seed companies. The discovery and development of cytoplasmic-genetic male sterility systems (CMS) in sorghum and pearl millet has made it possible to harness heterosis through the development of hybrids in these crops. More recently, the availability of CMS in pigeonpea has opened an avenue for commercial hybrids in this crop as well.

The relationship between ICRISAT and PS seed companies, especially in India, has evolved over time. In the past, ICRISAT played a nurturing role to the fledgling industry and provided breeding material, often through informal networks. As PS seed companies grew, they started to develop significant research and development capabilities of their own. ICRISAT scientists soon recognised that the Institute's traditional relationship with the national public sector, though important, was no longer the sole route to farm-level adoption of improved cultivars. The PS, being close to the hybrid seed merchants and farmers, has better and integrated perceptions of farmers' choice and needs (Gowda *et al.* 2003).

ICRISAT recognised PS seed companies as a valuable research partner for research on hybrid cultivar development and seed production. This led to the conceptualisation and initiation of Sorghum and Pearl Millet Hybrid Parents Research Consortia during 2000 at ICRISAT, the first of its kind in the entire CGIAR system (Reddy *et al.* 2001). Under this arrangement, each PS company provides a small grant each year for becoming a member of the Consortium. This arrangement was very effective as evidenced by 16 PS seed companies becoming consortia members for sorghum and 18 for pearl millet, with 11 being common to both crops by the end of 2003. The consortia funds were used to augment the ICRISAT core funds for research. The significant aspects of these arrangements are that the funds received from the PS companies are used to address the core research agenda of the institute to generate scientific information and breeding products that remain in public domain as IPGs, and are available freely to the public sector (Gowda *et al.* 2004; Reddy *et al.* 2005). The

second phase of HPRC was operative during 2004–2008, and 50 PS seed companies were members of one or more consortia — sorghum, pearl millet and pigeonpea. Currently, this consortium is in phase 3 of HPRC, operative since January 2009.

Synergies in public–private partnerships

Most people agree that there are synergies to be gained by a combination of the social equity of the public-sector research institutions and the efficiency in product delivery of the private-sector companies, creating linkages in the supply chain for delivery of inputs (in this case seed of hybrid cultivars) to small-holder farmers at reasonable costs. Pooling of resources minimises the risks involved in R&D, for mutual benefit. Sharing of investment costs leads to lower product costs, thus benefiting the consumers.

ICRISAT is involved in strategic research as well as in applied research that includes pre-breeding and development of improved breeding lines and hybrid parents that are shared with all its partners, including the private sector. The private-sector companies further select among the breeding lines to identify good parental lines and produce and test experimental hybrids for suitability in different agro-ecological niches. Seed of selected promising hybrid cultivars are then multiplied rapidly, processed, packed and marketed using the vast network of agro-dealers in the rural areas, for purchase by small-scale farmers at rural markets.

Benefits to resource-poor farmers

In India, the HPRC membership involves about 50 seed companies. Involvement of large number of companies increases competition among them and reduces monopolistic behavior. The cost of hybrid seed is kept at reasonable levels by competitive forces, hence remaining within reach of resource-poor farmers. Adoption of hybrids is rapid because farmers get higher yields and increased income. The incremental seed cost (of hybrid seed vis-à-vis open-pollinated varieties) is offset by higher incomes to farmers because of higher yields from hybrid cultivars that have greater yield potential. Seeds of hybrid cultivars are now available in remote rural areas because of the extensive market networks of the PS seed companies, leading to rapid adoption of high-yielding hybrids. ICRISAT provides a diverse range of hybrid parental lines each year, enabling PS companies to market several genetically diverse hybrids, reducing disease epidemics. For example, there have been no pearl millet downy mildew epidemics in India during the past two decades, mostly because of the diversity of hybrids under cultivation (by a conservative estimate, more than 80 hybrids — by name — were marketed by seed companies in India in 2008). A similar genetic diversification of hybrids has occurred in sorghum, with more than 50 hybrids reportedly cultivated in 2008. Adoption of diversified hybrids in pigeonpea is at the farm-level testing stage.

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Vegetables and Small Private Sector Interests

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Poor farmers in developing countries need access to affordable high-quality seed of improved crop varieties to improve their incomes and reduce malnutrition. Vegetables are vital for balanced nutrition, particularly in Africa, where production has been almost static for decades, per capita consumption is very low and malnutrition is rife. Vegetables produce much greater income than staples and farmers are willing to pay substantial amounts for good seed of open-pollinated varieties they can later reproduce themselves. Small local seed firms have a competitive advantage over multinationals in supplying niche markets provided by large numbers of smallholder farmers and in dealing with complex seed distribution chains, but they need public-sector research support. AVRDC — The World Vegetable Center's vegetable breeding research and the business expertise of small private seed companies are delivering improved varieties to smallholder farmers in developing countries where there is limited public-sector plant breeding capacity. Over the last ten years AVRDC has worked closely to build partnerships with national agricultural research services and local seed companies in Tanzania to create effective national seed systems and to breed and widely distribute a series of improved tomato varieties, revolutionising East African tomato production and increasing farmer incomes by an average of 40%. Similar close cooperation is successfully commercialising improved varieties of Africa's highly nutritious indigenous vegetables — previously ignored as food for the poor. International research cooperation and public–private partnerships also are increasingly important to vegetable industries in Australasia and the Pacific as national agricultural funding priorities change, diseases become more internationalised, and quarantine alone is insufficient insurance against transmission.

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AVRDC — our expertise

Partnership is the mainstay of the research and development activities conducted at AVRDC — The World Vegetable Center. Founded as the Asian Vegetable Research and Development Center (AVRDC), but now with a global mandate, the Center has a long tradition of successful collaborations in many countries. With development being part of AVRDC's founding mandate, the Center is in a unique position — compared to most other international agricultural research centres — to adapt research for development.

Since 1971, improved vegetable varieties have been one of the major success stories of the Center's research and development program, and more than 571 000 seed samples have been distributed to the public and private sectors in more than 180 countries. Working with exotic (introduced) and indigenous vegetables, the Center has employed a participatory approach involving

farmers, national partners, the private sector and other stakeholders in the inception and execution of research projects. This partner involvement has led to great success in the implementation and utilisation of the Center's genetic resources and other technologies, thus creating impact and helping to alleviate poverty and malnutrition through improved access to appropriate seed, varieties and improved vegetable production technologies. Facilitation of the vegetable seed supply chain is vital so that vegetable farmers can have ready and timely access to new varieties and information on improved production technologies. However, not all regions and farmers have benefited equally from the Center's advanced vegetable lines, as lack of infrastructure in many developing countries and an underdeveloped seed sector, particularly in sub-Saharan Africa, have hindered accessibility.

The private sector has been, and remains, a very important partner group for AVRDC and is essential to the effective dissemination of new seeds. These partners range from large international entities to small, local entrepreneurs. AVRDC actively supports the private seed industry by providing improved inbred lines that accelerate variety development, sharing disease screening and seed production protocols, and conducting training in genetic improvement, business management and market chain issues. To increase the availability and rate of dissemination of high-quality seed, location-specific alliances need to be formed and coordinated with those companies and public-sector organisations capable of fulfilling necessary breeding, selection, varietal registration and marketing activities. The clear understanding that it takes more than just investment to create a dynamic, sustainable seed sector is paramount for a positive outcome.

Building partnerships with small vegetable seed producers

Successful partnerships depend on mutually accrued benefits. It is essential that these partnerships grow from a shared vision with well-defined and agreed goals and objectives typically captured in Memoranda of Understanding or Agreement documents between AVRDC and these partners. AVRDC traditionally has focused on the development and production of open-pollinated varieties (OPVs), which may be less commercially exploitable than hybrid seed but are favored by low-income farmers unable or reluctant to invest in higher-priced improved hybrid seed.

Obstructed by existing poor seed distribution networks, AVRDC and other public-sector institutions need to partner with small domestic seed companies that still perceive OPVs as a viable market niche and possess the marketing infrastructure and expertise to deal with a diverse distribution chain of middlemen. Vegetable seed is smaller and much more valuable than seed of grains or pulses; it is a viable commodity for small seed companies with limited storage and transport capacity that are prepared to invest in the greater complexity of vegetable seed production and distribution. Benefits to be derived by the partner seed companies include advanced knowledge of potential new varieties, their characteristics through the national testing procedure and suitable production techniques.

Although experience has shown that profit generation is a strong motivator for consistent and reliable partnerships, identifying the 'best fit' private partners in terms of size, ability, community penetration and marketing experience is essential, and should be tailored to each location. Smaller seed companies often have greater local experience than large multinationals, and can better identify and characterise niche market demands in their region.

It is vitally important to link private partners with national agricultural research and extension services (NARES) and non-governmental organisation (NGO) collaborators to strengthen national seed systems. AVRDC and our partners employ a participatory approach to variety selection and testing that involves on-station and on-farm variety evaluation with various groups (farmers, students, NARES, NGO and private-sector personnel), thus ensuring partner involvement and ownership of the results from project inception to completion. This helps ensure our vegetable breeding activities meet real market and consumer demands.

Promotional activities such as field days, seed fairs and on-farm or on-station demonstrations are undertaken across the partnership spectrum to provide farmers direct access to varieties and information on vegetable production technologies with an unbiased perspective. AVRDC promotes improved lines through information leaflets, distribution of seed kits for home gardens, training programs for farmers, and workshops for collaborating scientists prior to official varietal release.

The inclusion of stakeholder representatives from the public sector is required to facilitate the active cooperation of public regulator agencies for variety release, registration, seed health and quarantine, and to broaden development linkages. Participation of the public sector in the ownership of the improved seed material expedites the regulatory process and minimises the time needed for variety certification and approval for release, which often can be a bureaucratic stumbling block in many countries. For example, in sub-Saharan Africa AVRDC works closely with partners such as the Tanzania Official Seed Certification Institute (TOSCI) and the Kenya Plant Health Inspectorate Service (KEPHIS) for varietal registration and certification issues, and with national agricultural research institutes such as those in Namulonge, Uganda, and the Ugandan National Agricultural Advisory Services (NAADS). These are linked to the 20 or so small private-sector companies operating in the region such as the Alpha Seed, East Africa Seed, Victoria Seed and Kibo Seed companies. These, in turn, are linked to the pro-seed activities of farmer groups, civil society organisations, church groups, women's groups and NGOs such as Farm Concern International and Catholic Relief Services who interact with and train the farming community.

Production and distribution of AVRDC tomato varieties in Africa

A partnership between AVRDC and local seed companies in Tanzania has helped make improved tomato seed available to farmers across East Africa, creating a new regional seed industry and a new source of income for highland farmers in Tanzania. Tomato is a very important cash crop grown by small- and medium-scale farmers in large areas of mainland Tanzania. For decades Tanzanian tomato production was relatively inactive with poor-performing, old-fashioned varieties (Marglobe, Moneymaker, Cal J and Roma — some dating back to the 1920s) continuing to dominate the market. These varieties are low-yielding, mostly susceptible to pests and diseases and are easily damaged during transportation due to their thin outer skin. The high cost of seed of European hybrids put them beyond the reach of smallholder farmers and such varieties are not necessarily well adapted to local environmental conditions.

Over the last decade, AVRDC and its NARES and NGO partners successfully developed two new tomato varieties, Tanya (processing type) and Tengeru 97 (fresh market type), that were released by the Tanzanian Horticultural Research Institute in 1997. These varieties not only yield more than the old varieties but, due to their firmer outer skins, are substantially less vulnerable to pests and diseases as well as to damage during road transportation. They are also more resistant to tomato mosaic virus, fusarium wilt and root knot nematodes. The new varieties possess the advantage of longer shelf life, potentially lasting in a saleable condition for up to three weeks at room temperature.

Seed of these varieties was disseminated to small- and medium-scale farmers in all the important tomato-growing areas of the country. Horticultural researchers, in collaboration with AVRDC, the seed unit in the Ministry of Agriculture, Food Security and Cooperatives, private seed producers, and extensionists disseminated the varieties through the formation of producer and marketing groups, seed production groups, farmers' exchange visits, and multi-locational demonstration plots. They also collaborated with other elements of the private sector, seed stockists and agro-dealers to ensure the availability of high-quality seed to farmers.

Tanya became the first locally adapted processing variety suitable for year-round production. Full-fleshed, juicy and suitable for eating fresh or cooked, Tanya (short for 'Tanzania Nyanya' from the Kiswahili word for tomato) has become the country's most popular variety. Tanya provides smallholder farmers with about 36% higher yields, and better prices in the market place, compared to the best older varieties (Lyimo *et al.* 2005). Sufficient supplies of high-quality seed were critical to this success, and one key means of achieving this was through a partnership with Alpha Seed Company, a small family-owned Tanzanian business. For more than 15 years, Alpha Seed Company has worked with AVRDC and its other NARES and NGO partners to produce and market seed of new varieties. There were diverse aspects to this collaboration, including the annual provision of sufficient breeder's seed for eventual bulking into certified seed, and training Alpha employees and contract farmers in all aspects of producing high-quality seed efficiently and profitably. The company was involved in demonstration trials and seed fairs to promote the new varieties. Alpha worked with AVRDC to help fabricate simple, farmer-friendly fruit maceration and seed separation equipment derived from AVRDC prototypes, and was supported by scien-

tists to ensure the purity and productivity of its seed production fields.

Since 2002, East Africa Seed, Kibo Seed and Multiflower/Royal Sluis Seed Companies also have been producing seeds of Tanya and Tengeru 97. The seed is produced close to AVRDC's Regional Center for Africa (RCA) at Arusha in Tanzania's dry upland area. The combined production by all the seed companies currently exceeds 15 t per year. Many young people in the region have been attracted by the income potential of tomato seed production, with some returning from jobs as labourers in the local tanzanite gem mines to become tomato contract growers.

The recent Tanzanian government evaluation of the impact of Tengeru 97 and Tanya on community livelihoods by Lyimo *et al.* (2005) showed that there had been a considerable increase in the area of tomatoes under production and in average yields in the seven years since their release, with net income gains for an average tomato producer of 21%. Six years after their introduction, more than 67% of farming households in tomato-producing districts in Tanzania grew Tanya and or Tengeru 97. The adoption intensity as measured by the proportion of the total crop area planted to the new tomato varieties in 2002–2003 was 58% and this had increased to 81% in 2003–2004. The new varieties have average yields of around 70 t ha^{-1} compared to 52 t ha^{-1} for the other older varieties. With the average variable cost of production being 17% lower, growing the new varieties produced an overall net income increase of 40%.

The new varieties are now known beyond Tanzania, as buyers come from neighboring countries to get supplies of the new seed and fresh tomatoes that possess a longer shelf life. The seeds and produce are being marketed in more than a dozen countries including Kenya, Uganda, Democratic Republic of Congo, Zambia, Malawi and Zimbabwe. The seed also is being exported to as far as Mauritius and the Middle East. The increased income from growing these improved varieties has made a major difference in the quality of life of farming families in tomato-growing districts. In some districts in Tanzania, more than 90% of farmers have been able to build new homes, buy vehicles, open shops, pay school fees or medical bills with the income earned from selling the fruit of these new varieties. The health of farmers and consumers has improved because the new varieties have somewhat better nutritional value than older varieties and are available for consumption over a longer period.

Meru, a new tomato variety bred by scientists at AVRDC and introduced into several African countries in December 2007, is rapidly becoming a favorite among Tanzanian farmers for its demonstrated resistance to late blight, a common disease that can significantly reduce tomato yields. Meru produces good yields of quality tomatoes under climatic conditions that favor development of late blight. To supplement the rising demand for late blight resistant tomatoes another new variety, Kiboko, was released in December 2008. The breeding pipeline continues to flow forward. New early-blight and late-blight resistant varieties with even greater potential than Meru and Kiboko currently are being evaluated in on-farm and multilocational trials involving all private, public and NGO/community-based organisation (CBO) sector partners.

The role of partnerships in establishing an enhanced market for indigenous vegetables

In parallel to research and development efforts with exotic vegetables such as tomatoes, the Center also works in active partnership with the private sector in Africa to develop indigenous vegetables. Most African diets are highly unbalanced, but a solution can be found in the indigenous vegetables often seen growing along roadsides and on uncultivated land. African fruit and vegetable consumption per capita is less than half the internationally recommended level and well below other developing regions of the world (Weinberger and Lumpkin 2005). Vegetables are one of the most important sources of vitamins and minerals and are a vital resource in the battle to overcome deficiencies of vitamin A and iron, which are major contributors to the scourge of malnutrition in Africa (AVRDC 2003). Indigenous vegetables are an important source of nutrition in Africa — particularly for the poor. For example, a survey by AVRDC in rural Tanzania found that African indigenous vegetables provided up to 50% of the beta-carotene (vitamin A precursor) and 25% of the iron requirements for the poorest members of the community — far higher proportions than for wealthy local consumers (Weinberger and Msuya 2004). African indigenous vegetables are surprisingly nutritious compared with common exotics such as white cabbage and standard red tomatoes. Researchers at AVRDC have found they contain higher levels of beta-carotene and vitamin C plus greater levels of vitamin E, folate, calcium, iron, zinc and anti-

oxidant activity (AVRDC 2004). This observation is common and germane throughout much of the developing world where malnutrition remains at crisis proportions and is particularly the case in Sahelian West Africa, the Ethiopian Highlands, the Great Lakes region and areas of southern and eastern Africa where maize is the dominant food staple.

AVRDC and its partners have developed improved lines, growing techniques and cooking methods for crops such as amaranth, spider plant, African nightshade, Ethiopian mustard and African eggplant that are fueling a resurgence in the popularity of indigenous vegetables in both rural and urban areas. Currently, producers find these crops are in high demand. The Center has been able to enhance the nutritional value of indigenous vegetables for consumers by modifying traditional recipes. Leafy vegetables are usually simply boiled or stir-fried, but researchers have demonstrated that adding oil, tomato, lemon, soybean and a combination of different indigenous vegetables can potentially increase the human bioavailability of beta-carotene by 50% and iron by over 50% (Yang and Tsou 2006; Ngegba *et al.* 2009). These recipes have been published in leaflets and distributed to farmers directly or through AVRDC's partners. In addition, researchers at AVRDC in Arusha, Tanzania and Hyderabad, India, have developed improved agronomic practices that can integrate up to 14 different kinds of vegetables in optimised home garden systems. Using these innovative cropping patterns, yields of over 80 t ha^{-1} y^{-1} can be obtained to provide a household's daily vegetable requirement year-round (Chadha and Oluoch 2003; Chadha and Oluoch 2007; AVRDC 2008a).

Home seed packs

Home garden packs containing elite lines of indigenous and exotic vegetables have been developed by the Center and widely promoted in East Africa to progressive farmers, womens groups, NGOs and schools during short-term training courses in growing, processing and preservation and cooking of vegetables. In Tanzania alone almost 8000 seed packs were distributed in 2007. In partnership with 23 seed companies in Eastern and Southern Africa, the Center is helping seed companies commercialise improved lines of African indigenous vegetables to ensure they can play their vital part in overcoming malnutrition in Africa (AVRDC 2008a).

For example, selected high yielding lines suited to local tastes are being promoted to farmers in East Africa with the help of local NARES, the private sector and NGO partners. In partnership with local seed companies and the NGO Farm Concern International, AVRDC's Regional Center for Africa has introduced improved lines of nightshade (sweeter varieties), spider plant, vegetable cowpea and African eggplant in Kenya and Tanzania. Supermarket displays and innovative promotions in formal and informal markets have raised urban consumer awareness of these indigenous vegetables. Working with more than 900 farmers organised in business support groups and linked to markets, sales of indigenous leafy vegetables such as giant nightshade grown with seed sold by the Simlaw Seed Company increased from 31 t in 2003 with an estimated farm gate value of USD6000 to 600 t in 2006 with an estimated farm gate value of USD142 860 in Nairobi, Kenya, alone (MATF 2007; Ngugi *et al.* 2007). The volume of sales has apparently continued to rise, particularly in supermarkets such as Pricerite and Uchumi in Kenya and in the informal rural and urban markets of Tanzania and Kenya.

Amaranth

Leaves of amaranth (*Amaranthus* spp.) have been a traditional food across Africa for centuries. Three improved lines introduced by AVRDC and possessing softer, sweeter leaves than the older types have created a new industry for small peri-urban farmers in East Africa. The new varieties can be harvested in just 21 to 28 days and have reduced cooking times. The nutritional value of amaranth depends on how it is cooked. Leaves plucked from traditional varieties are much tougher than the soft young whole plants harvested from the new varieties, and are usually cooked for up to 40 minutes. At AVRDC in Arusha, Tanzania, women farmers have learned recipes for the new varieties that use cooking times of as little as 10 minutes. This maximises the nutritional value of amaranth and helps save fuelwood — an added bonus in a region where wood is in short supply due to dwindling forest cover.

Seen as an inexpensive high-protein substitute for meat, the demand for this highly nutritious vegetable has contributed to the growth of a viable seed sector in East Africa. Local seed companies in Uganda released new amaranth varieties such as White Elma and Green Gina and sales have expanded as consumer awareness of the nutritional value of these traditional vegetables has grown. In Tanzania and Kenya, other seed com-

panies, AVRDC and NARES are promoting and demonstrating these lines prior to local release.

African egg plant

In Tanzania, AVRDC has had a success story with African eggplant. For years 'garden eggs' as they are commonly known in much of Africa, were literally just that — a backyard crop ignored as a potential income earner because of low-quality varieties, a perception that it was food for the poor, and competition from exotic crops like tomatoes and the eggplant common in the rest of the world. Selection work conducted by AVRDC from 2000–2005 identified the varieties Tengeru White and the premium-priced and sweet-tasting DB3, AB2 and RW14 as having great market potential. The new lines now dominate markets around Arusha. DB3 can be harvested every week for seven months, and produces for up to 15 months if pruned back at the end of the season. Because of its scarcity and high demand, it can fetch up to three times the price of the other new variety, Tengeru White. Farmers can harvest ten to twenty 30-kg bags of African eggplant each week throughout the seven-month growing season and earn USD2500 ha^{-1} a year, which is almost twice the income possible from tomatoes (AVRDC 2008b). Today African eggplant regularly appears on the shelves in the supermarkets that cater to the region's wealthiest consumers. Local seed companies have started scaling up seed production using AVRDC protocols, but there is still a need to improve marketing channels. A recent socioeconomic impact assessment of households' participation in growing African eggplant in four villages in Arumeru district near Arusha determined the magnitude of commercialisation of African eggplant. Families growing African eggplant were found to have significantly higher values in almost all parameters of commercialisation, including time spent by household members, income levels and ownership by gender. It was ranked as the current number one cash crop (AVRDC 2008a).

Lessons learned

Quality seed is an essential input for the production of vegetable crops needed to balance the world's nutritional requirements. Promoting the use of improved seeds and suitable crop husbandry techniques are of particular importance for poverty alleviation. A united team approach involving private- and public-sector institutions and farmers that combines each partner's unique strengths and expertise is required to enhance demand, increase the resilience of production systems and improve the livelihoods of the poor. The production of quality seed requires mastery of two kinds of expertise:

- technical knowledge of seed biology combined with skills to overcome biological restrictions
- managerial skills required to run a seed business.

Both skills often are lacking, but the former is best found in public-sector research organisations such as AVRDC and the NARS, and the latter is far better executed by the private sector. In addition it is important to have strong and transparent national seed regulatory systems in place to assure the availability of foundation seed to the companies. Only by working in coordinated public–private partnerships can we hope to strengthen the seed systems in Africa and ensure easy access by farmers to locally adapted, affordable seed.

AVRDC's strategy for vegetable improvement has been to supply national agricultural research centres and private companies with germplasm and semi-finished varieties through material transfer agreements in which the intellectual property rights remain, where possible, fully in the public domain. Although not perceived as profitable by large multinationals, OPVs continue to be widely planted and may actually possess longer projected niche market life expectancy than hybrid seeds. Working in partnership with the private sector has provided AVRDC with a good understanding of the use and management of intellectual assets, of intellectual property rights and how to protect these rights to ensure the Center's target clients are able to access the technologies they need from the Center. However, there is no ideal intellectual property rights (IPR) system for plant breeding due to widely differing seed systems between crops and among and within countries. Our experience in working jointly with private and public partners and negotiating agreements has further underscored the importance of clarifying intellectual property rights beforehand to ensure an appropriate balance is achieved between public interest and incentives for the participating company. Information and varieties generated through AVRDC's projects will remain international public goods.

Future role of AVRDC

Improved performance of the smaller seed companies fosters a competitive seed sector and helps to make access to locally adapted seeds affordable to smallholder farmers; this in turn will lead to increased productivity. AVRDC is committed to continuing to support local seed companies with variety testing and seed multiplication of breeders' seed. Training and assistance in the development of realistic and practical business plans as well as seed marketing and dissemination strategies are also provided. AVRDC will continue to facilitate the training of NARES and NGOs in production technologies, and foster vegetable production and consumption by building networks that ensure all public- and private-sector stakeholders are well linked and understand their respective strengths, roles and common goals. Malnutrition also will be targeted by fortifying partnerships with NARES and NGOs to disseminate improved production technologies and establish linkages with institutions promoting community health.

Although the development of small seed companies is being fostered through the establishment and or improvement of seed distribution channels, a balance between profitability and sustainability is necessary. It would appear that small- to medium-sized seed companies at present have a potential competitive advantage in meeting the needs of farmers in sub-Saharan Africa due to their flexibility and niche market orientation. Their participation is essential in addressing food security, malnutrition and poverty reduction issues within economically disadvantaged rural communities. However, due to their small size, it is unlikely that they would develop in-house breeding capacity for a wide range of crops. Investing in public-sector breeding research and ensuring research outputs reach the private sector in a functional and timely manner is a major way in which all partners can contribute to the food and nutritional security of the poor.

It is an inescapable fact that funding for public-sector research, particularly for long-term efforts such as plant breeding, has diminished drastically over the last decade. This trend runs strongly counter to national and regional interests and to the likelihood of achieving the Millennium Development Goals. Enhanced future investment in agricultural research remains a sensible strategy both nationally and internationally, and good public–private partnerships with small companies remain a vital component in ensuring this investment is fruitful.

Why is this paper of importance to Australian donors and to vegetable research in Australia?

Australia's vegetable research programs are superficially collaborative, with shared funding between government and industry through Horticulture Australia. In reality, the division of interests between commodity focus groups, grower groups dominated by recent immigrant communities, a lack of industrial levy funding for major national crops like tomatoes, competition between state research organisations and the evaporation of their longer-term funding support has considerably weakened the vegetable sector and its potential future development.

In an open and developed economy, local seed companies have to survive in a climate of international competition. By world standards, the Australian vegetable industry is relatively small, with many players and diverse environments over wide agro-ecological zones. Given the size of the local market, it has therefore been difficult for local vegetable seed industries to survive. As a consequence, virtually all major Australian seed companies are now internationally owned. Fewer than ten small- or medium-sized local vegetable seed companies produce specialist lines, and these receive little breeding support from government. To a large extent, Australian vegetable growers rely on imported varieties, as international companies have scanned the world and know what to breed for if the market is large enough and can pay. Australian government breeding programs provide some locally adapted germplasm for larger vegetable industries such as tomatoes, brassicas, sweet corn and capsicums, but much more investment has been made in working with seed companies in the much larger pasture and field crop industries.

The recent epidemic of tomato yellow leaf curl virus in Queensland's winter-season tomato industry surely demonstrates that effective research investment would have helped in reducing the current risk to this major national industry. Australia's reliance on international seed companies can lead to considerable problems when new disease races or pests appear and there is no public breeding program to provide sources of resistance. Although this devastating disease has not been found in this region previously, its profligate global expansion should have been sufficient warning that palliative investment in

international agricultural research efforts to achieve resistant germplasm would have been a good national insurance policy. That this lesson is neither unique nor probably the last such experience to occur in Australia, irrespective of stringent quarantine laws (N.B. the devastation of *Ascochyta* blight in chickpeas in Western Australia in the last decade) should alert public-sector investors to the need for supporting suitable international agricultural research. Moreover, they also need to ensure that the domestic plant breeding sector is maintained and the pipeline of young Australian plant breeders, pathologists, entomologists and other agricultural professionals from universities continues to flow. At present, national underinvestment severely threatens this outcome.

When there is an imbalance between the contributions of the public and private sectors, marketing can by default shape what farmers grow more than agronomic suitability. Varieties often are commercially successful because large companies have the marketing presence to advance specific lines, despite their agronomic limitations. Increased pesticide spraying of a less-well-adapted but widely marketed variety may become the default response to a new pest or disease problem because it is uneconomic for the private sector to develop a resistant variety for a small market, and the public sector no longer has the capacity to carry out the work. The public sector needs the private sector, as varieties produced in public programs usually have no easy path to commercialisation unless the program is funded by, or aligned with, a large international company with the means to distribute and market seed. The private sector needs the public sector to provide the best-adapted germplasm for locally important industries that may not be globally significant.

Active government research breeding programs and collaboration with local seed companies can create whole new industries to benefit local farmers and create export opportunities. For three decades the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and state Departments of Primary Industry in Queensland and New South Wales led plant breeding efforts to produce locally-adapted mungbean varieties using AVRDC-derived germplasm, working in close collaboration with local seed companies and the industry association. This created the Australian mungbean industry, and the crop is now the country's most important tropical grain legume.

Government support for the development of Australia's native foods through the Rural Industries Research and Development Corporation (RIRDC) has encouraged the rapid development of the industry, as evidenced by the recent formation of an industry peak body, Australian Native Food Industry Limited. Without government support, indigenous crops would not have developed into viable mainstream industries or potential sources of income for indigenous communities, and knowledge of their value and cultivation may have been lost. International agricultural research organisations such as AVRDC are doing the same for indigenous vegetables worldwide.

The current Australia – New Zealand 'Vital Vegetables' initiative is an excellent example of the benefits of combining government research and development efforts with the expertise of smaller private companies to bring improved, nutritionally enhanced vegetables to market to benefit local consumers and to help local vegetable industries maintain a competitive export edge in a global marketplace.

Safe vegetable production is one of the most effective ways of creating prosperity in the developing world. International agricultural research organisations such as AVRDC — The World Vegetable Center have an important role in working with small private companies to build national vegetable industries in countries where governments do not have the expertise and quality vegetable seed production and marketing are poorly developed.

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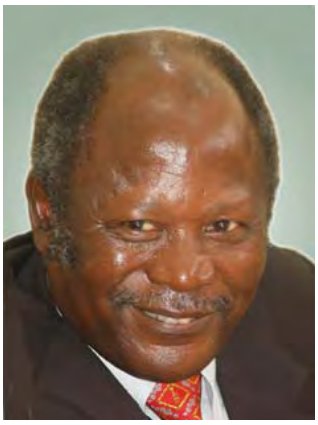

An African Green Revolution Leading to Development

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Africa is short of food, due particularly to increasing population and under-investment in agriculture and agricultural research. For several reasons farm yields are about one-quarter of the global average. New broad cooperative approaches to the problem have had very encouraging results; Malawi for example has been able to export food to neighbouring countries. Significant factors in this success include comprehensive policy support by governments for farmers, innovative financing arrangements, and institutional innovations that have encouraged small-scale domestic agribusinesses, especially in the supply of good seed and fertiliser. There are further opportunities to build on the resulting expansion of rural economies, for example by new crops and local processing, and to extend these examples to other countries. Increased vigilance is required to maintain farmer access to good farmland, and to anticipate and offset adverse effects of climate change.

Dr Namanga Ngongi has had extensive experience in agriculture and management of international organisations. He worked in Cameroon in the ministry of agriculture before being assigned in 1980 as representative to the UN food agencies in Rome. He joined the World Food Program in 1984 and became Deputy Executive Director in 1994. In 2001 he was appointed Special Representative of the UN Secretary General to the Democratic Republic of Congo, and led the peace-keeping mission (MONUC) for two years. He helped put together the transitional government. Dr. Ngongi retired from the UN in 2003. He joined the Alliance for a Green Revolution in Africa (AGRA) as its President in November 2007. Namanga obtained a BS in agriculture from the California State Polytechnic University in 1968, and MS (1973) and PhD (1976) degrees from Cornell University.

Introduction

It is a great honour to address this conference on behalf of AGRA, the Alliance for a Green Revolution in Africa. The Chairman of our Board, Mr Kofi Annan, former Secretary-General of the United Nations, extends his warm regards.

I thank the Crawford Fund for its dedication to addressing a central issue of development: the effective use of research to achieve food security, especially for Africa, where one-third of the population faces chronic hunger.

Today's gathering is indeed impressive, as it brings together public and private partners who have within their collective grasp the opportunity to help transform African agriculture, which has long languished even as other world regions have doubled and quadrupled their productivity.

Africa has a problem: there is not enough to eat. Africa has been food-insecure for decades. Per capita food availability has declined; more than 250 million Africans live with daily hunger. Meanwhile agricultural imports are on the rise, especially for rice, wheat and even maize — the continent's most important food staple.

AGRA works across the agriculture value chain, in partnership with the public and private sectors, to transform the subsistence existence of our smallholder farmers into viable commercial activity. Make no mistake: agriculture in Africa is smallholder agriculture. Seven out of every ten Africans gain their livelihoods through farming. Most are women, and most cultivate a hectare or less of land. Their yield is one-quarter the global average. Working with little more than a hoe and some saved seed, they struggle to feed a continent

of nearly one billion people. It is time to ensure that they have what they need to succeed.

To do so, we must be willing to break with old orthodoxies and ingrained ways of working. We must think out of the box to put in place the programs, policies and partnerships that can rapidly increase farmers' productivity, add value to their goods, move those goods to markets, increase incomes and employment, and launch Africa on a path of prosperity and food security.

We are talking about nothing less than an African Green Revolution — a uniquely African and sustainable Green Revolution that will not only beat the odds of today, but also those of tomorrow, those being thrust upon the continent by climate change. Everything we do must not only improve productivity today, but also consider tomorrow, and help the farmer adapt to and mitigate climate change, and protect the natural resource base upon which all of farming depends. But I am speaking to Australians — and you know what I am talking about. Like Africa, Australian agriculture has already felt the hot dry winds that can come with climate change. We cannot afford to wait to address this problem or it will be a total catastrophe, especially for Africa where 70% of the population depends on agriculture for our livelihoods.

Africa's Green Revolution must deliver proven scientific innovations to farmers without further delay! It must transfer research results into development. While basic research will and must also continue, there are so many existing technologies that have yet to reach our farmers. These research results must be adapted to African conditions and put to wide use in the field.

Today in Africa we find that even when new research is used, it is often not used at a scale large enough to attract the attention that it deserves. Take conservation agriculture for example: everyone knows it works. Farmers can plant trees in their fields to improve soil fertility, but in most cases trees alone will not solve farmers' problems. They must be combined with other interventions. The question is, how do we link things up and carry out demonstrations of a scale that will catalyse change for thousands?

Take the situation in Kakamega, in Western Kenya, an area with enormous agricultural potential but even more poverty! Unlike so much of Kenya, it has plenty of rain. What it doesn't have is good soil. Acidic soil depresses yield by at least 30%. But this problem has a solution — one used all over the world — lime. And, in fact, there are two regional lime companies; there are agro-dealers to sell the lime to farmers. There is a research centre developing new seeds and soil management practices; there is an extension service to train farmers in use of lime and conservation agriculture. But until recently there was no way to link up these distinct parts of the value chain as there was one major missing ingredient — finance — loans affordable to smallholder farmers and agro-dealers so that they could purchase the lime, fertilisers and seeds to stock, sell and grow. Now, thanks to an innovative program by AGRA and Equity Bank, such loans are available, and lime is on its way to thousands of farmers, with a target of 50 000, in a program sponsored by AGRA and coordinated by KARI–Kakamega.

Success will come when we find the right ways to link all things together. We can then achieve system-wide change that benefits smallholders. To link things together we need to build public–private partnerships that think outside the box. New approaches and guiding principles are emerging from recent successes across Africa, and I would like to share six of these with you.

1. Comprehensive policy support

Malawi, in Southern Africa, is a great place to start. The government also broke with conventional wisdom when it boldly decided to provide smallholder farmers access to inputs, storage and good pricing. For decades, support of any kind for Africa's farmers had been condemned by international development partners — despite the fact that support for farmers was clearly essential to the success of farming in developed countries. At any rate, Malawi broke the mould. The government facilitated access by smallholder farmers to improved seeds and fertilisers from agro-dealers through a voucher system. It worked brilliantly: not flawlessly, but brilliantly.

Government support translated into increased farm productivity and growth of the private sector. Other government policies supported the development of roads, irrigation and innovative marketing boards.

As a result of this comprehensive approach — and the blessing of good rain — Malawi averted famine and became a net exporter of maize. It has now been self-sufficient in maize for four straight years, exporting its surplus and giving 10 000 metric tons of maize as food aid to Swaziland and Lesotho. This year, it will export maize to Kenya, whose harvest has been crippled by drought.

This shows us that African governments must be supported in developing their own home-grown policy solutions that provide farmers with comprehensive support. We cannot underestimate the significance of such a change. For decades, African governments have neglected agriculture, sometimes in efforts to meet the mandates of international donors, whose structural adjustment policies called for replacing public-sector involvement in agriculture with private sector. While perhaps good in theory, it didn't work for Africa and the result was disastrous.

Even today, African governments on average devote just 4–5% of their national budgets to agriculture. In contrast, during the height of the Asian Green Revolution, Asian governments were dedicating over 15% of their total government spending to agriculture. Then, as now, we get what we pay for.

But African government priorities are changing. The African Union's Comprehensive African Agriculture Development Program, known as CAADP, commits governments to dedicating 10% of national budgets to pursue 6% annual agricultural growth. So far six countries have met this goal, and others are stepping up.

2. Innovative finance

Another example of successful innovation is in Tanzania. Last year, 700 000 smallholder farmers in the Southern Highlands produced five million tons of maize. It was a record-breaking year, which the Minister of Agriculture attributed in part to the government's partnership with AGRA, whose programs are increasing the availability of good seeds and fertilisers with the help of a revolutionary new finance program for smallholder farmers and small- and medium-sized agri-businesses.

AGRA and its partner, the Financial Sector Deepening Trust, put up $2 million to guarantee $10 million worth of loans made by the country's National Microfinance Bank (NMB) to support smallholder farming. Meanwhile, as in Malawi, the government put in place a program of farmer support, with vouchers for farmers use to purchase seeds and fertilisers from rural agro-dealers. At the same time, new seed varieties developed by the national agricultural research organisation and distributed by AGRA-supported seed companies were reaching farmers. This combination of affordable finance — enabling agro-dealer to stock their shelves and farmers to buy inputs, often with the support of government vouchers — led to impressive increases in farmer productivity. The World Bank even took note, and is supporting the extension of the government's voucher program with $160 million.

Since AGRA first launched its innovative financing program in Tanzania, it has built on this success. We have leveraged US$160 million for funding small-scale farmers and African agri-businesses. Standard Bank, one of Africa's largest financial institutions has provided $100 million to be disbursed in Uganda, Tanzania, Ghana and Mozambique. Equity Bank in Kenya, one of Africa's fastest-growing financial institutions, has allocated $50 million, with AGRA and the International Fund for Agricultural Development each injecting $2.5 million as security.

Such financing represents a total break with past lending practices by African commercial banks, which have made less than 1% of their lending available to smallholder agriculture. New operating principles are at work including loan guarantees that reduce banks' risks of lending to agriculture; the development of appropriate financial products for farmers; improved performance of agricultural markets; and efforts to improve farmers' financial literacy. These approaches make it possible for banks to provide low-interest loans for smallholder farmers — a win-win situation.

AGRA is moving quickly to build on these successes. We are now working with partners to develop a syndicated loan guarantee facility that will leverage one billion Euros from commercial banks into smallholder agriculture.

3. Institutional innovations

Rwanda, in Central Africa, is also making major strides in feeding its people. As part of this silent revolution, the government has increased farmers' access to fertiliser. To do so, the government of this landlocked country rocked the boat. It ended the state's control over fertiliser distribution. Such control was totally ineffective! Instead, the government devised a way to involve and strengthen the private sector. The government imports fertiliser in bulk, and auctions it to the private sector, which sells it to farmers. Some of this distribution goes through village-based agro-dealers, reaching farmers far from any paved road. As a result of this and other innovations, Rwanda's food production grew by 15% in 2007 and 16% in 2008: a green revolution is in the making.

Another institutional innovation is networks of agro-dealers: small-scale business women and men who work in remote rural areas, getting farmers affordable high-quality seed, fertiliser and other inputs they would otherwise either go without, or have to walk many kilometres to find.

Today, AGRA is strengthening agro-dealer networks in eight countries in Eastern and Southern Africa, and three countries in West Africa. In just four countries — Malawi, Tanzania, Kenya and Zambia — AGRA has funded the training of 4500 agro-dealers, leading to the certification of more than 3500. They have collectively sold 115 700 metric tonnes of fertiliser and 35 285 metric tonnes of seeds to farmers.

Agro-dealers represent a thriving new branch of Africa's agricultural private sector, and need to be scaled up further to reach tens of millions of smallholder farmers with affordable, appropriate farm inputs.

Other institutional innovations are needed, such as countries banding together for regional procurement of fertiliser. Currently, on average, African farmers use one-tenth the amount of fertiliser used elsewhere in the world, leaving three-quarters of farmlands severely depleted of soil nutrients. The price of fertiliser is totally beyond reach of most smallholder farmers. One way to lower the cost is to purchase in bulk, and AGRA is working with the African Development Bank to open a Fertiliser Financing Facility which does just that. Meanwhile, AGRA is also supporting national efforts to develop African fertiliser manufacturing capacity.

4. Developing Africa's agricultural private sector

The potential of the private sector in African agriculture may be one of the continent's best-kept secrets. Imagine it: hundreds of millions of smallholder farmers are essentially private businesses. The problem is that, until now, they have been failing businesses. This is changing, and as it does, the opportunities of Africa's economic growth will blossom.

In the past, when populations were much smaller, people could be happy with annual food production of one ton per hectare. It was sufficient to feed a small population. That is no longer the case. The possibilities of making a decent living with low-input agriculture have dwindled. There is clearly a need for locally adapted, improved seed; integrated soil-fertility management which blends organic and inorganic nutrients; small-scale irrigation and other technologies that make the most of soil moisture and rainfall; and other farm inputs.

To really flourish, smallholder farmers need opportunities to add value to their crops. They need to be able to process cassava into flour, turn bananas into baby food and combine grains into high-nutrient energy bars. Everywhere one looks in African agriculture there are opportunities for business growth and development.

The paradox is that African agriculture has not attracted the interest of research and commercialisation efforts, especially those operated by the private sector. This is both because African agriculture has been low-input, and because we have so many diverse agro-ecologies.

The seed sector is a good example. Smallholder farmers are in desperate need of improved, locally adapted seed — but seed development must be tailored to the location and conditions. Africa has dozens of staple crops and hundreds of varieties of those crops that must meet consumer tastes as well as local ecologies. This offers great scope for small-scale businesses, but not much for large-scale businesses that can sell billions of dollars worth of a single seed type.

Recognising that small- and medium-sized African businesses must be the core of a private-sector revolution in agriculture, AGRA has provided start-up capital for 32 African seed enterprises in 23 countries. In two years or less, most of these companies have doubled their production of

improved seed. They are selling every last seed produced — and could sell even more. African entrepreneurs are hungry for the opportunity to grow businesses that serve smallholder farmers.

There are, however, continuing challenges for these young companies, challenges that span the value chain, and many in simply establishing smooth collaboration between the public and private sectors, and increasing capacity at the rate and to the scale needed. For instance, a continuing challenge faces smallholders who grow legumes, such as cowpea, pigeon pea and soybeans. These crops are packed with protein and nutrients and their use improves soil fertility. However, because they are self-pollinated and can be retained by the farmers for several planting seasons, seed companies do not make big profits for selling them as seeds. They have been among the many 'orphan crops' of Africa, neglected by R&D. While African crop breeders have begun to develop improved high-yielding varieties of legumes and a few companies are multiplying and disseminating them, the challenge now is finding ways to support community-based organisations or farmers' groups to produce the improved varieties in quantity for sale to local farmers.

5. Breadbaskets and land grab

All of these innovations, from improved high-quality seed to affordable finance, will be most effective when they are linked together, especially in areas that have the highest potential for rapid agricultural growth: Africa's breadbaskets.

Breadbasket areas have relatively good rains, soil and infrastructure; large numbers of smallholder farmers; and governments committed to agricultural development. The question is how best to develop these areas.

Recently, a spate of land deals has been consuming huge tracts of African farmland. Although the headlines have faded, this trend has not gone away. As a result, countries and corporations from China, Great Britain, Qatar, Saudi Arabia, South Korea and other countries have entered into deals with governments from Kenya to Sudan, Congo, Mali, Senegal, Mozambique and Zambia. African governments have been trading away some of their best lands in exchange for one-time investments. African countries who are net importers of food and reliant on food aid are now bargaining their futures away, often with little transparency, regulation or environmental oversight. And smallholder farmers are losing their already tenuous rights to the land.

It need not be so. African countries would benefit more — in terms of broad-based agricultural growth, increased food security and lower food prices — by investing in their own breadbaskets in ways that benefit the smallholder farmers who work them. In some situations, African countries can negotiate mutually beneficial terms with foreign investors. To create a win-win situation, these terms must include and uphold the interests of smallholder farmers. They should bring investment capital, training opportunities, infrastructure development and skills that benefit smallholder farmers.

Primarily, however, Africa must invest in its breadbaskets for its own benefit. This will take strong partnerships and significant resources, especially in the area of infrastructure development. Africa's roads, power grids, storage facilities, clean water supplies and irrigation systems are all areas crying out for investment which is essential to the success of an African Green Revolution.

Africa has less infrastructure today than Asia had in the 1950s, and the negative impacts are staggering. It costs $3000 to ship a container from Mombasa to Kigali next door. Whereas transport is 15% of the cost of the fertiliser to Asian farmers, it adds 40% to the cost of fertiliser to the African farmer.

One other thing is needed for breadbaskets to realise their potential: Africa's farmers, especially its women farmers, must become better organised. They must aggregate to strengthen both their political power and their negotiating power. Farmers can use aggregation to improve their access to markets, including the carbon market.

6. Climate change

Climate change is perhaps the largest challenge facing Africa's smallholder farmers. It could derail Africa's Green Revolution.

Africa did not cause climate change — the continent contributes less than 3% of global greenhouse gas emissions — but we now bear its brunt. Climate change poses major threats to Africa's smallholder farmers and to the continent's food security. Mounting temperatures and intensified droughts are predicted to cut the yield of rain-fed agriculture by up to 50% in Africa. An

African Green Revolution must urgently help farmers to adapt to climate change. This will take technological, institutional and policy innovations, many of which can come only from public–private partnerships.

At the same time, Africa's smallholder farmers can and must be part of the global solution. They can help mitigate climate change through sustainable farming practices that sequester carbon and conserve forests across hundreds of millions of hectares of land. Their efforts should be valued and included in the global carbon market.

Conclusion

We reap what we sow. If African farmers are able to sow their fields using the high-quality improved seeds of Africa's staple crops, using fertilisers tailored to the soils, crops and cropping systems of Africa, using sustainable soil, land and water management techniques, then they will reap enough to feed Africa and to help feed the world. If we apply the power of knowledge and technology to meet the needs of smallholder farmers, their communities and the natural environment we can transform African agriculture into a highly efficient, productive, competitive and sustainable system. This is the way forward for an African Green Revolution and for achieving a food-secure and prosperous Africa, a full partner in the pursuit of a food-secure and stable world. Let's put our heads together, be bold, think outside the box, and commit ourselves to the changes needed.

Linking Asia's Farmers to the Global Economy

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The world's population is estimated to peak at around nine billion in 2050, with almost half of the increase from 2009 (three billion) occurring in Asia. This will require a doubling of food production on a declining land area and natural resource base and in the context of increasing climate variability. At the same time, however, increasing urbanisation and the globalisation of food production are creating new opportunities for smallholder farmers in Asia to make a transition from subsistence agriculture to more-specialised production systems linked to commercial food production systems. Driving this transition will require increased investment in more-efficient and robust agricultural production technologies and a greater focus on enabling supply chain opportunities for small-scale farmers. In most countries in the region, government extension services have been unable to engage effectively with commercial supply chains. In several cases, the commercial sector is signaling demand for commodities from supply chains based on networks of small-scale producers. Using examples from the region, this paper highlights key issues that enhance smallholder competitiveness in these supply chains.

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Introduction

To meet the demands of a world population predicted to peak at nine billion by 2050, it is predicted that the world will need to increase annual food production by 70–100% over that same period. This is a complex challenge made all the more difficult in most developing countries by declining natural resources in existing agricultural land, limited new areas for agricultural production, increasing variability of weather cycles exposing farmers to widening risks, highly disaggregated production systems with inadequate supporting infrastructure and or services in many areas and a lack of supportive policies and financing. The required gains in food productivity (let alone nutrition) will need to come from sustainable intensification of agriculture ('producing more food from the same land area while reducing the environmental impacts') (Godfray *et al.* 2010). There is no shortage of promising technical options to underpin this intensification (such as more effective integration of cropping and livestock production systems, conservation agriculture, improved water and nutrient management, GM varieties, reduced post-harvest losses) but most of these options require investments of time, capital and knowledge that have been beyond the reach of many of smaller-scale farmers. There has been a consequent widespread trend for farm families to invest their limited cash resources in educating children so they can leave the land, resulting in an aging and decreasing rural population and a stagnation of agricultural productivity. Reliance on remittances from city-based offspring is a widespread phenomenon that underpins the survival of many rural communities. All of these factors mitigate against the emergence of smaller-

scale agriculture as a profitable business enterprise attractive to a new generation of farmers. In some cases, this is creating pressures for consolidation of smaller-scale farms into larger units that are more commercially viable, and while this may be beneficial in some regards long term, in the short to medium term it produces pressures that existing social safety nets cannot handle.

This somewhat bleak scenario for smaller-scale farmers is not necessarily an endgame. There is a growing number of examples where rapid globalisation of agrifood and agro-industry supply chains has driven large and profitable businesses to develop via (or catalyse) a network of smaller-scale producers. Prominent among these examples are (i) rice production in the major lowland areas of Vietnam, China and Thailand for international markets and (ii) vegetable production in small fields supplying the boom in supermarkets. In a paper on cassava supply chains in Vietnam, Nguyen and Cuna (2005) commented:

> Agrifood value chains have become the dominant force in the global food system, and one that presents both potential opportunities and threats for the poor. The question is not whether to participate but how to do so in way that best improves well being. The major threat is that the poor will be bypassed, or even harmed, by the development of these chains. At the same time, their involvement might offer real opportunities for sustainable livelihood improvement.

This paper summarises five cases of agro-industries and agrifood supply chains that rely on large networks of smaller-scale farmers and examines the factors that enhance (or are needed to maintain) the competitiveness of the farmers in those chains.

Case 1: Cocoa in eastern Indonesia

Indonesia is the third-largest producer of cocoa in the world with ~90% of the ~500 000 tonnes of dry cocoa beans produced each year coming from smaller-scale farmers. Around 500 000 farm households, with cocoa plots averaging 0.5–1.5 ha, are dependent on this global cocoa supply chain in which they receive at the farm gate more than 80% of world prices (Panlibuton and Meyer 2004). Cocoa contributes export earnings to Indonesia exceeding US$1.4 billion per year with steadily rising prices, doubling between 2006 and 2009.

The Indonesian cocoa industry developed in an ad hoc way through the 1980s when labourers returning from working on cocoa plantations in Malaysia started growing cocoa in their backyards at a time when cocoa prices were relatively high. During the first 20 years, this was a profitable livelihood as cocoa plots were relatively disease and pest free and soil fertility could sustain production with very low labour inputs. In recent years, however, increasing pest and disease pressure, aging tree stock and declining soil fertility are threatening the viability of cocoa production as a small-scale enterprise. Average dry bean yields of 400–800 kg ha^{-1} are as little as half the potential yields if these factors were controlled (Fig. 1). Estimated resulting annual production losses of 240 000 tonnes of dry beans equate to lost value to farmers of US$280 million per year or over roughly US$400 per year per farm family, a significant sum in a country where formal-sector workers receive an average salary of less than US$125 per month. Added to this are losses of as much as US$70 million per year from quality-related discounts. The net effect is that farmers are now achieving <60% of their potential economic returns from growing cocoa, while labour inputs needed to maintain present yields are increasing to levels beyond the capacity of many farm households.

The challenges facing the cocoa industry in eastern Indonesia are not dissimilar from other agro-industry supply chains linked into small-scale farmers: the production base is fragmented among a large number of producers and productivity constraints require investments of capital and access to knowledge and new technologies that

Figure 1. New disease- and pest-resistant varieties are an important driver of revitalisation of the cocoa industry in eastern Indonesia. (Photo: David Guest, University of Sydney)

are difficult for small-scale farmers to implement. Cocoa production is potentially a very profitable and productive enterprise for smaller-scale farmers if production constraints can be overcome. Five relatively simple and robust management practices have been identified that can largely eliminate the main productivity-limiting constraints: declining soil fertility, aging tree stock and increasing disease and pest pressures. Despite large training programs being implemented over the past ten years for up to 100 000 farmers, uptake has been very limited. A key issue limiting uptake is that the transition from low-input systems to managed, higher productivity systems is not simply a matter of demonstrating to farmers the economic benefits of the transition. There are risks in the transition (such as insecure land tenure), borne out of decades of experience among farmers that bad times follow good. A farming strategy based on reducing risk in the longer term is a sound survival strategy for subsistence agriculture, but it makes the process of transition towards a more-commercially oriented production system a much more cautious one.

In 2008, the Indonesian Government embarked on an ambitious US$340 million program to revitalise the cocoa sector in eastern Indonesia. A key driver for this revitalisation has been the development of new disease- and pest-resistant clones, but this in itself is not sufficient to revitalise the industry. It has been recognised (Neilson 2009) that the program will also need to:

- provide ongoing field support to farmers in making the transition to more-productive and sustainable systems
- implement pro-farmer policies
- involve commercial supply-chain participants in the revitalisation process
- implement innovative ways to improve farmers' access to financial service so they can invest in these new production systems.

Case 2: Cassava in Vietnam and Thailand[16]

Cassava is a relatively easy crop for smaller-scale producers to commercialise as they can make a gradual transition from growing cassava for home use to growing it for global markets, without changing the basic production systems. In that process of transition, if global markets are volatile or supply chains relatively new, farmers have other options, including using the cassava to feed their own animals or selling it in local markets. Over a period of 25 years, the cassava industries in Vietnam and Thailand have been transformed from being a backyard food crop grown by farmers as a safety-net should cereal crops fail to a major agro-industrial crop for the starch and animal feed industries (Figs 2, 3). Thailand and Vietnam are now the world's largest exporters of cassava products, earning Thailand about US$1.4 billion annually. In 2007, almost 2.1 million farmers in Vietnam and 0.5 million farmers in Thailand were growing cassava for these supply chains, all of it on relatively small farm areas (0.3 ha in Vietnam and 2.6 ha in Thailand) (Hoang *et al.* 2008a).

Figure 2. Farmers can make a gradual transition from growing cassava for home-use to growing it for global markets. (Photo: Neil Palmer, CIAT)

Figure 3. A doubling of cassava yields in the last 20 years has been due partly to widespread adoption of new varieties. (Photo: Neil Palmer, CIAT)

This remarkable transformation has been underpinned partly by improvements in yield and partly by increases in area. In 2008, cassava fresh root production in Vietnam was about 9.4 million tonnes, up from only 2.0 million tonnes in 2000.

[16] Much information in this case was provided by Dr Rod Lefroy (Centro Internacional de Agricultura Tropical; CIAT)

This was achieved through both a doubling of areas planted (from 240 000 ha in 2000 to 560 000 ha in 2008) and a doubling of average yields (from 8.4 t ha^{-1} in 2000 to 16.9 t ha^{-1} in 2008) (Hoang *et al*. 2008b). These yield increases have resulted partly from broad adoption of new, higher-yielding industrial varieties emerging from 25 years of breeding and selection (now >60% and almost 100% of areas planted in Vietnam and Thailand respectively are using new varieties). The transformation has also been driven by parallel investment in the commercial sector. In 1990, for example, there were no medium- or large-scale starch factories in Vietnam, but by 2008 there were 60 factories with a processing capacity of 3.2–4.8 million tons of fresh roots per year, all grown by smallholders (Hoang *et al.* 2008a).

As with the cocoa industry in Indonesia, the cassava industries in Vietnam and Thailand are facing problems associated with a history of ad hoc development, a production base fragmented among a large number of producers, and emerging serious productivity constraints that require capital, new knowledge and new technologies that are difficult for small-scale farmers to access or implement. In Vietnam, cassava supply chains generally lack coordination and have many layers of participants with low margins and low value-generation along the chains (Nguyen and Cuna 2005). This becomes a key impediment for an industry that has, until now, supplied bulk starch into a raw commodity market. Greater coordination of supply chains will be needed if the smaller-scale farmer production networks are to take advantage of emerging specialised markets which need cassava as a feedstock, in particular bioplastics and ethanol. In particular, policies that promote access to credit are needed for the smaller firms that coordinate these supply chains to survive (Goletti *et al.* 2001). There are also emerging challenges around sustaining productivity. The rapid expansion of cassava into new areas has often meant it is planted on sloping land and soils vulnerable to erosion and fertility decline. New potentially-devastating pests and diseases have just started to emerge in the region (CIAT 2010).

Case 3: Seaweed in eastern Indonesia

Indonesia is the world's largest producer of RAGS ('red alagal galactin seaweeds'), which are a source of hydrocolloids used in a wide range of processed foods. In 2007, Indonesia produced 2.1 million fresh tonnes of RAGS, about double the production of 2000 (McIlgorm and Dworjanyn 2008). World demand for RAGS is forecast to double between 2007 and 2012 (Neish 2007). Almost 90% of RAGS production in Indonesia comes from an estimated 500 000 small-scale producers in coastal communities of eastern Indonesia (Fig. 4). With the widespread and catastrophic decline of fish resources upon which coastal communities depend and with very few other options (especially for remote communities and households that do not own agricultural land), cultivating seaweed to produce a product for global markets is a vital livelihood option.

While the industry has a bright outlook, it has also suffered from recent wild fluctuations in prices and supply that threaten the viability of the producers. Contributing factors include poorly coordinated supply chains and lack of access to market information, declining yields at any location after a few years, and a lack of research support for improving the clones used in cultivation. Furthermore there is no value added at source, either by farmers or regional buyers, despite high potential. Dried whole seaweed is currently shipped from remote coastal communities to Java for processing. As the recovery of

Figure 4. A farmer drying seaweed on the roadside in South Sulawesi (Photo: Peter Horne)

carrageenan (a gum; the dominant product from RAGS in Indonesia) is <30% by volume, 70% of the seaweed is discarded. This not only contributes to very high transport costs per unit weight of seaweed (squeezing profitability for all supply-chain participants) but the 'waste' component has high concentrations of nutrients and plant growth promoters which are needed in the remote communities from which it came to sustain agricultural productivity. Households wishing to start farming seaweed also face substantial initial investment costs to buy necessary infrastructure and these costs are especially hard to meet in remote communities. For the industry to survive and meet predicted rising demand, producers need equitable access to financial services.

Case 4: Shrimp in Indonesia[17]

Coastal pond aquaculture in Indonesia, which is dominated by shrimp culture, employs around 480 000 farmers in an industry worth close to US$2 billion annually, largely for export. The production systems are dominated by small-scale producers. In South Sulawesi province, for example, with an estimated 60 000 producers, 46% are classified as small scale (<2 ha) and only 23% as large scale (5–10 ha). Two main species of shrimp are produced in these systems: the traditional tiger shrimp (*Penaeus monodon*), and the recently-introduced white shrimp (*Litopenaeus vannamei*). Tiger shrimp live on the pond floor so volumes and yields are relatively low but their management is relatively easy. White shrimp float throughout the pond, are more resistant to disease, have higher survival rates, tolerate higher stocking densities and grow faster but their management is relatively more intensive and requires larger investments in infrastructure and inputs (Yi *et al.* 2009). Despite the large numbers of small-scale farmers using 'extensive' or 'traditional' culture practices, their contribution to total production is only about 5% as they are facing an increasing array of challenges. The emergence of a viral disease affecting *P. monodon* production in the 1990s doubled harvest failure rates among small-scale producers to as high as 50% (Yi *et al.* 2009). Rising input costs and increasing competition and quality demands in the domestic and international markets compounded these problems. While improved management practices have been identified to control disease (including incorporating liming and cleansing, aquaculture rotations and polyculture, disease-free seedstock and isolation techniques), adoption by small-scale farmers has been very low. Adoption by these farmers is hindered by limited access to new knowledge and the costs and risks associated with significant upfront remediation investment. They are also less able to participate in the trend towards increasing production of *L. vannamei* (with its higher productivity and greater disease resistance) because this requires more-sophisticated management and greater inputs. Unlike some other agricultural systems (as with cassava), intensification of production from 'traditional' to semi-intensive systems is not a gradual pathway. Consequently, small-scale farmers will need to make significant and radical investments in both resources and skills to adjust to semi-intensive shrimp aquaculture. The net result 'is forced and chosen disadoption [of shrimp farming], … by small traditional farmers — who find feed costs too much in the face of dwindling yields due to *P. monodon* disease'. Yi *et al.* did conclude however, that 'From a poverty alleviation and small farmer income development viewpoint, the … most promising finding is the emergence of at least some small farmers who are capable of participating in modernizing supply chains. **The study's most worrying finding is that to 'play the modernising game', producers need both market sophistication and scale**. The study concludes that 'small shrimp farmers can participate in modernizing chains, and gain from that participation, by either entering into contract schemes or by starting cooperatives and by making investments in production and traceability capacity'.

Case 5: Cashew in Indonesia[18]

Cashew production occurs in some of the driest, remotest and poorest regions of eastern Indonesia and it is a significant source of livelihood for about 400 000 farmers. The crop is largely exported as nut in shell to India and Vietnam for processing, with total exports in 2005 worth about US$70 million. Cashew is in a sense a 'gathered bounty' for these farmers, providing them with a source of income for very low input. As a result of

[17] Much information in this case is from ACIAR Project FIS/2007/124: Diversification of smallholder coastal aquaculture in Indonesia (http://www.aciar.gov.au).

[18] Information in this case is from ACIAR report FR2008-13: *The Potential for Cashews in Eastern Indonesia*, by Ian Baker and Julian Witjaksono, February 2008 (http://www.aciar.gov.au/publication/FR2008-13).

the minimal management, cashew productivity is typically very low (<500 kg ha^{-1}) with returns to farmers of only US$250 ha^{-1}. The combination of high transport costs, low productivity, lack of local or even national processing and a fragmented production system mean that the margins for all participants in Indonesian cashew supply chains are tight. Without greater investments in productivity, supply chain coordination and local processing, it is hard to see how these farmers can remain competitive in a global market. Despite this challenging outlook, there are longer-term options for improving farmers' returns by 200–300% (through simple orchard management and use of higher-yielding varieties with larger kernels) and for adding value through local processing of nut-in-shell. This will require substantial investments in research on new clones and both government and private-sector support for major industry revitalisation.

Challenges for competing in rapidly changing markets

The cases described above illustrate some of the challenges that smaller-scale producers currently face to be able to compete in a rapidly changing and globalising market environment. Figure 5 illustrates these changes in terms of two key factors that influence these farmers' decisions about the transformations their production systems are facing: **labour demand** and **investment demand**. Figure 1 positions each case on a scale of these two factors with a broad trend from top left to bottom right (as indicated by the arrow) as these production systems **transform** and become more market-engaged and aligned. Production systems towards the left of Figure 1 tend to be disconnected from technical services, business support services, financing mechanisms and markets, whereas those on the right are more connected. This broad trend of transformation of production systems linked to large numbers of smaller-scale farmers involves a transition from ad hoc or opportunistic production systems (as is the case with cashew in Indonesia) to planned and production-oriented systems (as is happening with shrimp production in Indonesia).

The transformations that have taken place in the first four cases involved substantial risks to smaller-scale producers that continue to limit the extent to which they can take advantage of growing opportunities in the global economy. These include risks associated with:

Figure 5. Current labour and investment intensity for five case studies (the arrow indicates the general trend of transformation affecting these industries)

Sustainability

Moving towards a greater alignment with market opportunities encourages a focus on optimising yields and quality, sometimes at the cost of accelerating decline of the natural resource base (as in the case of cassava expanding onto sloping lands in Thailand and Vietnam). Intensification without sustainability is threatening several of the supply chains described above.

Specialisation

Diversification of agriculture is a common strategy for minimising exposure of farm households to economic, climatic and political risks in smaller-scale farming systems. Transformation in these agro-industries has necessitated a degree of specialisation that brings with it exposure to a level of risk that may not be perceived by farmers at the time. So, for example, when coffee prices peaked in the early 1990s, thousands of poorer farmers in the central highlands of Vietnam converted all of their land to coffee, despite the fact that they were on sandy soils and without access to irrigation water. When coffee prices fell in 1999 to 25% of their former levels, these marginal farmers were extremely vulnerable, having removed all of their other crops (Connell *et al.* in press).

Transition from self-sufficiency to a market focus

Making the transition from a focus on self-sufficiency to a focus on production for market is not a simple process driven by farmers'

analysis of economic costs and benefits. In some cases, farmers will take great risks in planting large areas to a new crop on a promise made by buyers that they will return to buy all production. On the other hand, tens of thousands of cocoa farmers in Indonesia have consciously chosen not to adopt new technologies for good reasons, such as low returns to labor and lack of access to credit — despite the fact that these technologies are robust, simple and capable of doubling yields. Cattle raisers throughout South-East Asia routinely receive prices for their animals (per kilogram liveweight) between 150 and 200% of those received by farmers in developed countries, and yet uptake of management practices that can increase growth rates by 50% is generally slow. **Sustained transition to a market orientation is most common when driven by reliable and well-coordinated supply chains**.

Access to key resources

For many (such as most cashew farmers in eastern Indonesia and shrimp farmers in South Sulawesi), the transition to greater market alignment may be beyond reach simply because of lack of easy and cheap access to key resources needed to underpin sustainable intensification of production including technical inputs, knowledge, finance, infrastructure, a supportive business environment and markets.

Despite these challenges, smaller-scale producers are able to compete very effectively in some regional and global supply chains because of specific conditions in those supply chains that favour smaller-scale production, including:

Economies of scale

Some supply chains require labour-intensive inputs and yet are not necessarily suited to commercial or plantation scale (e.g. seaweed in Indonesia). Plantation or nucleus estate systems tend to emerge when there are economies of scale, such as needing minimum feedstock supplies before processing mills can be established (e.g. oil palm and rubber). In the case of cassava in Vietnam, plantation approaches did not emerge partly because of disaggregated land systems but also smaller-scale producers could access starch processing micro-enterprises or sell their dried cassava for animal feed.

Market opportunities targeted at smaller-scale producers

Niche markets are growing that favour specific smaller-scale production systems, such as organic and fair-trade coffee, and organic vegetables. Supermarkets are also presenting a rapidly growing opportunity for farmers in Asia, and while the access requirements for small-scale producers may be prohibitive (such as food safety, quality, processing and packaging), some factors do open market access opportunities. These include:

- larger farmers may have broader marketing options making them a riskier sourcing choice for supermarkets
- smaller-scale farmers may be better able to implement rigorous and labour-intensive management practices required by the market
- smaller-scale farmers may be able to reduce the transaction costs to companies by forming effective cooperatives
- larger companies may prefer to provide inputs directly to smaller-scale producers in managed supply chains to guarantee supply and quality (Reardon *et al.* 2009).

Market segregation

With growing urbanisation and the emergence of a larger middle class in many Asian countries, there are opportunities for market segregation providing access for smaller-scale producers to specific markets. For example, rising incomes and increasing awareness of the health benefits of milk in Indonesia are expected to increase demand between 2009 and 2013 by 17.1% for fresh milk and 22.5% for milk powder. Consumption growth of fresh milk in non-urban areas is limited by poor infrastructure and access to refrigeration. These constraints mean that fresh milk is still unavailable in large parts of the country. Other forms of milk, such as powdered and sweetened condensed milk, are however popular in Indonesia especially outside the main population centres as they are easier to transport and are less perishable (BMI 2009). In response to these demand patterns, Indonesian milk production is characterised by segregated supply chains: tightly managed supply chains feeding fresh milk from processors' own farms into the high-end urban fresh milk market, and outgrower supply chains

procuring milk from ~100 000 small-scale dairy farmers for the more-processed products going to the larger mass market (DA 2005).

Land disaggregation

Many supply chains that are linked in to large numbers of smaller-scale producers may exist largely because of heavily-disaggregated land ownership in the key production areas (e.g. cocoa in Indonesia and cassava in Vietnam). In many cases, however, this is not a recipe for success but simply the pathway along which particular supply chains have developed. The problems associated with heavily disaggregated supply chains have been illustrated in the cases above.

Conclusions

The case studies presented in this paper reinforce the view of von Braun and Diaz-Bonilla (2008) that:

> Technological progress, improvements in infrastructure, and the creation of markets are facilitating the commercialization of traditional agriculture, but globalization—and trade liberalization in particular—produces both winners and losers among smallholders. The winners have been smallholders who have either vertically integrated with agribusinesses or have devised institutional mechanisms (such as associations) for collective action. Also, smallholders who have access to better physical infrastructure and credit and who have benefited from capacity-building activities implemented by the public sector, private industry, or international cooperation have managed to integrate successfully. The losers have been farmers who are poorly endowed in terms of natural resources, assets, and infrastructure; who lack access to markets for outputs, inputs, and land, as well as financial services such as credit and insurance; and who have limited alternatives for off-farm employment.

For some agrifood industries (such as shrimp in Indonesia), the best option for the 'losers' may well be to diversify into other production systems. In other cases, however, there is a positive and promising role for governments, donors and R&D agencies to improve the competitiveness, sustainability and viability of farmers in global agro-industry and agrifood supply chains through:

- improving access to the technical inputs, technical and market information, innovative and equitable financing mechanisms (such as warehouse receipting), infrastructure and markets that are needed to bring about sustainable intensification of production
- implementing policies that provide a supportive financial and business environment
- research to overcome constraints to the levels of productivity that could be easily achieved using existing technologies, management systems and varieties
- supporting farmer alliances and organisations for group marketing of products and purchasing of inputs and development of stronger managerial skills
- supporting agricultural intensification that sustains the natural resource base of the farming system
- market incentives that make an easier transition for smaller-scale producers to move towards more-profitable agricultural enterprises
- encouraging improved environmental and social standards
- working within alliances of public-sector organisations, the commercial sector, research agencies, NGOs and farmers' groups to coordinate efforts to create coordinated, profitable and sustainable supply chains.

These suggestions may seem ambitious and yet, in the first four cases presented above, elements of all these points are being implemented by different supply chain participants and R&D agencies. The major challenge is coordinating these efforts between disparate stakeholders who may not normally work together. An example where this challenge is being addressed is the Cocoa Sustainability Partnership (CSP) in Indonesia (http://www.cspindonesia.org) (Neilson 2009). CSP joins together Hasanuddin University, the Indonesian Cocoa Industry Association, several major international buyers and processors, the Indonesian Cocoa and Coffee Research Institute, the Indonesian Cocoa Industry Association, provincial research and extension agencies, several NGOs and international R&D agencies to guide the development of a sustainable and competitive national cocoa industry. It is an approach with wider potential application throughout the Asian region.

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Comment, Questions and Answers

CHAIR: MICHAEL TAYLOR

Murray–Darling Basin Authority

Introduction

This session brings together the many questions that have been asked in the course of the day. There is no chance of getting through all these this afternoon, but the Crawford Fund will publish all the questions as part of the proceedings [p. 113]. Today we have listened to a wide range of speakers who have addressed that critical question that Crawford put before us: Can the private sector feed the poor?

I would like to review the way in which all the speakers have responded to that question. No one saw it as purely a private-sector issue of 'feeding the poor'. A number of speakers very importantly drew out the point that we are only too familiar with — the extraordinary challenge we face with the world's population expansion to some nine billion people over the next four decades.

MR MIKE TAYLOR was appointed Chair of the Murray Darling Basin Authority on 14 May 2009. He is an experienced senior public administrator, serving as Secretary for the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government (2004–2009), Secretary for the Department of Agriculture, Fisheries and Forestry (2000–2004), Secretary for the Department of Natural Resources and Environment, Victoria (1996–2000), Secretary for the Department of Agriculture, Energy and Minerals, Victoria (1995–1996) and Secretary for the Department of Agriculture, Victoria (1992–1995). He was educated at the University of Melbourne (B. Agricultural Science) and at the University of New England (Dip. Economics).

Along with that, if we actually manage well, growth in incomes will put even more upward pressure on the demand for food. At the same time there are constraints on land, serious constraints on water and increasing constraints from the global climate challenge. So a really major question is, how do we actually feed a dramatically different world population?

New participants

In addition to speakers who have already contributed to the conference, we have three new participants in this session. The first is Dr Kate Fairley-Grenot, the chair of the Rural Research and Development Council, the government's key advisory body in respect of rural research. She has also chaired a NSW grants selection committee and has been an associate director of Coopers Lybrand. An independent consultant, she has a background in plant physiology and science policy, and is a graduate of Sydney, Harvard and Sussex.

Next is Dr Gabrielle Persley, Chair of the Doyle Foundation, a Scottish-based charity that supports the role of science and technology in Africa. Dr Persley is a foundation supporter of the Biosciences East and Central Africa (BecA) Institute, which shares a research platform at ILRI in Nairobi. She also has had a long executive association with that body, and has previously been an advisor to the World Bank in biotechnology and a senior member of ACIAR in Australia.

The third new participant is Dr Prabhu Pingali, deputy director of Agricultural Development at the Bill and Melinda Gates Foundation. He was formerly director of the Agricultural Development Economics Division of the Food and Agriculture

Organization of the United Nations. He co-chairs the Millennium Ecosystem Assessment Panel's working group on future scenarios. He is the editor of the e-Journal of Agriculture and Development Economics, eJADE. He has had 25 years of experience in assessing the extent and effect of technology change in developing country agriculture, especially in Asia, Africa and Latin America, and was the director of the economics program at CIMMYT.

New approaches, in addition to those of governments, are emerging as to how we can address the future world food demand. Traditionally the R&D has been supply driven and government based, with private-sector organisations very much on the edge. Foundations such as the Bill and Melinda Gates Foundation are starting to reshape partnerships between the private and public sectors.

Question 1. Scaling up

Dr Pingali, we are starting to see changes in the approach to essential research and the advantages of foundations that are unconstrained by past mores and culture, but how we to scale up to the very large international effort that could actually help close the gap?

Dr Pingali: I will give a more detailed account of the work of our foundation later [page 101]. Let me start by explaining why the Bill and Melinda Gates Foundation became involved with agriculture, and then comment on scaling up. Much of the work of the foundation over the past ten years was health-related: addressing HIV AIDS, malaria, tuberculosis, etc. As that work was in progress it became quite clear that if the fundamental problems of poverty and hunger are not resolved the gains from health work will be quite limited. There are enormous numbers of poor, hungry people, particularly in Sub-Saharan Africa but also in South Asia. We concluded that we should focus on agriculture in those regions. Why agriculture? Agriculture has had a clear track record of being the engine of economic growth, of being the fastest way to reduce poverty. As we considered what we should do, we asked why the productivity of agriculture systems in such large parts of the world is so low.

Basically it is a consequence of market failure in the supply of inputs —seeds, agriculture services — output markets, etc. Second, there is market failure in the lack of focus of R&D systems on crops that are important to poor producers and poor consumers, and on traits that poor people are really interested in such as tolerance to drought or submersion. Private-sector R&D has not addressed needs of smallholders — poor subsistent producers of staple crops — especially in Sub-Saharan Africa. The third set of market failures has been to not connect small holders to the market system — local markets, supermarkets, international markets.

We decided to try to address each of these market failures through better science and technology, better policy and institutional investments, and by creating mechanisms by which transaction costs for smallholders could be reduced. We can do this at a scale that may be larger than that of other foundations, but even then what we can achieve will resolve only a very small part of the overall problem. So how do you go from this level of investment to a national or regional scale? We need to address that problem from the demand side, not from the supply side. From the demand side we need to remove the incentive constraints that smallholders face — to get the price policy right and remove discrimination against and taxation on the agriculture sector. Once the incentives are right, smallholders will invest in new technologies and new inputs and enhance their productivity. And that's crucial.

Governments must be more involved in putting in place the infrastructure necessary to make agriculture work — roads, transport, communication, irrigation investments, etc. In Sub-Saharan Africa the level of such investment is extremely low.

We need to create systems through which rural businesses can flourish. Remove unnecessary regulations, remove bureaucratic red tape, remove taxes across borders to create a rural business environment that actually attracts the private sector — not just the big multinationals, but the mum and pop private sector that runs the rural mill, the rural store, etc. That's absolutely crucial.

If you can get these areas right, I think scaling up takes place by itself.

Question 2. Urea deep placement

Dr Roy, the urea deep placement program has been great for yields and for the environment — but what about labour? Doesn't it put a lot more pressure on labour resources?

Dr Roy: That is an important and very interesting question. The labour required for deep placement is greater than for broadcast application, but at the same time only one application is needed in the planting season. In addition, the need for and cost of weeding is significantly lower. On the other hand, as the yield goes up quite significantly, the labour requirement at harvest is greater. We are analysing the labour requirement for the entire system, and seeing that at seasonal peaks there is a shortage of labour, but this is pushing up the daily rate for women's labour during both the application and at the first harvest.

Question 3. Trust in public–private relationships

I have a series of questions regarding trust that revolve around public investment in genetics and the private sector — how we deal with the issue of publication and exposure and on the other hand the need for profit in the private sector.

So, to Bill Niebur: You have described a partnership between the public and private sectors, but can you really illustrate some of those non-profit elements that you pointed out that are really of benefit to DuPont and Pioneer? How do you gain from these partnerships?

Dr Niebur: Our employees have come to us through public institutions. They gained their education and occupational opportunity in public institutions. Those people demand that we give back corporately to the public sector through partnerships, projects and contributions. As a corporation we need to be engaged with our employees, our talent pool. That is not for profit, but it allows us to retain the people that we've worked hard to attract and develop, and whose potential we ultimately fully realise. Secondly we, like other corporations, have strong external advisory panels that hold us to a very high standard to use the technologies, the discoveries, the inventions and the innovations that we translate those inventions into, for the public good, fulfilling corporate responsibility globally and legitimising our ability to operate effectively across borders.

We have been a seed company since the 1920s. We have the right to be that seed company only if we behave in a honourable and transparent and legitimate manner. In order to develop the technologies that are required today, we need the right to operate that is provided to us through partnerships with the public sector and by our employees. Our employees cannot fully realise their potential if we isolate them from the extraordinary talent that is present today in the public sector.

To Ms Armstrong: It is all very well to have partnerships in place between the public and private sectors, but a critical part of the public in the R&D framework is the free publication of information. How does Monsanto deal with that? Does it restrict the times at which material comes forth?

Ms Armstrong: When Monsanto engages in public–private partnerships there is a variety of ways in which we approach that issue. In the case of the Water-Efficient Maize for Africa (WEMA) project, my understanding is that we are giving the drought tolerance gene and its intellectual property to WEMA, who will own that property and will be responsible for delivery to the different seed companies involved.

Dr Niebur: There is debate in the press (for example in *Nature* in October) between academics and the private sector on the free use of commercial products and the publication of data, but the press is not the best place for the public and private sectors to work out such differences of opinion. We are disappointed with the treatment and the quality of the article. A follow-up article in the periodical *GM Crops* in October will give a more balanced view of the different perspectives. Organisations like Sygenta, Pioneer and others do actively work with public researchers to make their commercial products available for evaluation. We encourage it. This approach makes us legitimate participants in this new era of regulated traits and stewardship. We must partner in such a way as to not inadvertently create problems where none exist today.

Question 4. Market development and scale

Dr Ngongi, you provided an excellent encouraging example from Rwanda of a systematic approach to developing essential markets. When we return to the challenge of feeding nine billion people, however, scaling-up is really a major challenge. Without minimising the successes to date, how does the Alliance for a Green Revolution in Africa (AGRA) plan to foster the scaling-up process?

Dr Ngongi: Clearly AGRA can push, can catalyse and can show what is possible, but it cannot manage scaling-up throughout Africa. If it had more resources it could do a little more. National governments in Africa have to accept their share of responsibility. Food security is clearly the primary problem in Africa. Most governments in Africa are spending probably 25–30% of their national budget on the military; arguably they could spend quite a bit more on agriculture. They have undertaken to spend 10% of national budgets on agriculture, but only six have gone past the 10% mark — so there is still a lot to be done.

I hope the international community that committed $20 billion in the L'Aquila summit this year will come up with significant resources to support the effort being made by organisations such as AGRA to scale up the successful work being done in Africa. We have shown that in a few years a lot can be done: but we are just scratching the surface.

Question 5. Intellectual resources

Dr Ngongi, one of the great successes of what you've been doing is to gather a group of people who thought very clearly about how the market system might be developed — the markets themselves, the various sorts of merchants involved, the incentives and the farmers' vouchers. We do hope that those important international financial commitments to AGRA come to fruition, but perhaps the most valuable asset of AGRA is not financial but the intellectual capital of the network. How might you actually transfer the intellectual capital that put those systems together, rather than just money, to other centres of need?

Dr Ngongi: Fortunately AGRA is not implementing any programs directly: all the implementation is being done at country level by nationals at country level. We work with support from some organisations like the International Center for Soil Fertility and Agricultural Development (IFDC) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). At a national level we work with national research systems — they are the ones doing the research work. We're working with national seed companies.

We are building capacity by training people in African institutions. Of course a lot more can be trained — Africa has suffered an erosion of human resources over the last 20 years or so without replacement and training of the additional people who are needed to transform ideas into reality. Maybe we are now moving into a world in which knowledge alone is not enough. Management skills and essential services have to be built up. I would like to make one pitch: 70% of the producers of food in Africa are women, yet women form no more than 10% of the workforce in essential agricultural support services in Africa. If any donor or supporter was going to do something really tangible in Africa it would be to increase the percentage of women professionals in agriculture and food production.

Question 6. Capacity building

Dr Ngongi has brought out this important issue of scaling up capacity building and this is an area in which Dr Persley has been involved for a long time. Dr Persley, how can we do much better than we have done in the past?

Dr Persley: One has to think about capacity building in one of two ways: capacity building of who and for what. There is now a trend away from simply looking at capacity building as being only the training of individuals to also increasing the capacity of institutions. Over the past 10–20 years, of African scientists who went overseas to do PhDs, 60% never returned home. Not because they didn't want to come home, but because there was nothing to come home to in the form of adequate research facilities where they could pursue a career as scientists, or indeed agriculturists. Thus capacity building in Africa is building institutions in those countries to address African real-life problems, not only in the technical areas like plant breeding but in areas like intellectual property and regulatory affairs.

Finally, I endorse the comments of my distinguished colleague from AGRA regarding the need and opportunity to increase the capacity and the numbers of women scientists and agriculturists — people who perhaps really understand the role of agriculture. As I reflect on what we've heard today, perhaps we haven't thought and talked enough about the importance of capacity building in political leadership. And dare I say in this particular hall that building the capacity of political leadership in the developing world is absolutely critical, because the green revolution wouldn't have happened without Norman Borlaug and a few other people. It certainly wouldn't have happened in India without Indira Ghandi.

Question 7. The role of large multilateral organisations

Dr Ferroni, you left us with some very important take-home messages in four examples. You drew our attention both to seed and the way in which it had been managed in India, with great promise. (Similar very good initiatives were described by Dr Ngongi, including the supply of fertiliser through an auction process.) You talked about capacity-building in the way that Dr Persley has just advocated. You also challenged some of the framework around the insurance market, and you put a lot of emphasis on private–public partnerships. But in that account you did not talk much about the big multilaterals like the Food and Agriculture Organization (FAO). How do you see their roles in the partnerships that are starting to appear between the private and public sectors?

Dr Ferroni: I view the multilaterals as potentially extremely important. When we talk about multilaterals we might distinguish between entities like FAO — technical organisations of the UN system — and the international financial institutions such as the World Bank, the International Finance Corporation (IFC) and so on. IFC is potentially very important since we are talking about the creation of markets — input markets, output markets and the conditions to make them work. Also, two regional development banks, the African Development Bank and the Asian Development Bank, are significant in this context.

The Asian Development Bank has always had a sizable portfolio in agriculture. I am sure they are going over their books at this time to see what their Agriculture Program should look like now that agriculture and food security are very much on the political table — there is heightened awareness on the part of both donor and recipient country governments of these issues.

The African Development Bank is very actively looking at what agriculture could mean for them in future. They used to say, when asked about agriculture, that 'we don't directly work in agriculture, but we are engaged in infrastructure'. Infrastructure is extremely important; for example you can hardly over-invest in rural and secondary roads. I think, however, that they are now looking at agriculture in a new, much deeper way, at the African Development Bank, checking out new aspects such as agricultural R&D and how to better link farmers to markets.

FAO, on the other hand, is a more technical organisation. There are plenty of technical and policy issues that need to be addressed at the present time — for example, the whole incentive question and agricultural taxation which used to be important in Africa. There has been considerable improvement in this issue at the macro level, but there are unresolved micro-level issues that affect incentives and production possibilities that need to be addressed. In any case, I regard the role of the multilaterals, both technical and financial, as very important.

Dr Pingali: I wish to add to what Marco has just said. A multilateral institution that has transformed developing country agriculture is the CGIAR system. Without the investments that took place in IRRI and CIMMYT the green revolution would not have happened — and those investments were tiny investments. They lead to enormous change and scale-up and to an entire set of CGIAR research centres that have done enormously important work over the years. My concern, when thinking of the L'Aquila summit and the G20 meeting that took place in Pittsburgh and the new money that's supposedly coming in, is that nobody talks about investing in cross-national research. Cross-national research will fall through the cracks in these new funding arrangements. We need to be making a bigger noise to ensure that that doesn't happen, and at the same time we need to force the CGIAR system to modernise, to understand that the problems of today are very different from the problems of the 60s, and that the geographic focus is very different. And the CGIAR needs to come up with a new plan of action to ensure it is relevant in future.

Question 8. Declining investment and declining growth in productivity

That leads to a question to Dr Pardey who, as a good physician, diagnosed a fairly unhappy story about declining investment in agricultural research by governments in the western world going back into the mid 80s and staying there for a long time. Because of the long lags in payoffs from investment in R&D, we are only now starting to reap the consequences of that decline in the form of a falloff in productivity growth. Noting the responses of Dr Ferroni and Dr Pingali, Dr Pardey, would you reflect on the future opportunities that we should be looking for?

Dr Pardey: We have talked about market failures at a national level, but there are serious market failures at a global level. The spillovers that I referred to that are cross-national in nature are the very root of the problem. Whilst particular countries may be investing and developing instruments to invest appropriately in agricultural R&D, collectively at the global level there is large and increasing under-investment.

Regarding the CGIAR, Prabhu used his words carefully in drawing attention to cross-national research falling between the cracks, which is different from suggesting shoring up the CGIAR. Whilst like Prabhu I have spent many decades in the CGIAR, I've been careful to distinguish between the economic drive that is pushing towards greater international research and the CGIAR, which is related but different.

Some of those economic fundamentals relate to things that were hinted at in talks by Bill, Marco and others. It is not just pulling together expertise, talent and germplasm. Much of the market value of the big multinationals resides in their acquisition and management of information. That process is much more complex in a multinational dimension than in a national dimension. Therein lie lots of pitfalls, but also lots of promise in the payoffs from using that information to direct technology development and extension to those areas where substantial gains could be made.

There are platforms and models already in the private sector that could be adapted not only to public–private relationships but to public–public relationships, and between the CGIAR and national research institutions and so forth. There are grounds for much more efficient use of scarce dollars, not a doomsday scenario. There is no substitute for cranking up the levels of investment. Although we can become much more cost effective, unless the levels of investment are cranked up we are not going to achieve the results that are essential. That boils down to sustained political commitment. This is easy to prescribe, but much more difficult to make happen.

I was encouraged to hear the Foreign Minister, Mr Smith, the opening speaker today. Very few foreign ministers would talk about and seemingly understand the role of productivity and growth and economic development. That a pretty complex relationship to get your head around for a Minister of Foreign Affairs. The fact that those ideas were on the table this morning must give hope that this message is starting to filter up. The secret for real success will be not to make transience commitments in this area but, as Gabrielle was pointing about on the human capital and performance, to sustain financial commitment over the long term.

Question 9. Agriculture and nutrition

We do have a lot of private-sector involvement in germplasm for the horticultural industries — certainly in Australia, Europe and United States — although it doesn't have a large role in the public-sector R&D framework. Is that the reason we get such little traction on some of the unique work that you are undertaking? I've heard the pleas for Australian resources, but what of institutional connections?

Dr Keatinge: I do believe that the public and private sectors can work more closely together. One of the brilliant things about the private sector is that it is dedicated to seed quality. Quality is probably the most important thing that the private sector can bring to seed production and make available to farmers. If you're going to charge a reasonable amount of money for a packet of seeds, all of them must germinate. There is a big distinction and divide between hybrid and non-hybrid crops. The private sector is under pressure to make money, and really the only way to make money within the seed system is to grow hybrids. This then very quickly limits the number of crops you can and will work with.

We also have to gear up not just agricultural organisations but those nutrition and health organisations that have been working in the same areas of nutrition and malnutrition but in different ways. If we are going to join up the research of the public and private sectors we also should join up the research of the agricultural and health sectors. We haven't yet learned how to speak the language of health very well, but we are in the process of trying to do that. Development, we all recognise now, is a very complex affair and to look for simple solutions is probably futile. With good will and with the energy from all of the sectors that are available to us, however, we can have a substantial effect on the major problems. One of these at a global level is malnutrition, not necessary directly hunger. I would like to see the private sector address more attention to that problem, a task in which the public and private sectors can work more effectively together.

Question 10. Initiatives in Australia?

Dr Grenot, there have been some important take-home messages for Australia today, especially regarding research and development in the rural sector. Can you comment on these?

Dr Grenot: I am chair of an advisory council to our Minister for Agriculture, Fisheries and Forestry; my colleagues Cathy McGowan and Jim Pratley have also attended today. I do not directly represent the rural R&D corporations.

The corporations model was established by John Kerin, who is here today, when he was minister for agriculture during the 80s. Thus we have an established mechanism in our system for building public–private partnerships. In addition we have ACIAR, examples of whose activities have been described today and which address various global issues.

A feature that distinguishes current partnerships involving research and food security in Australia from those of the post-depression and post-war eras is that this cooperation is now occurring in a global context made more complex by climate change. We anticipate that our nation state and its research systems (generally and especially rural R&D) will have to closely integrate with international research efforts.

I am therefore greatly heartened by what I have learnt today. I would hope the board of every corporation will consider how they can match their export-orientated commercial ambitions and the public-good requirements that come with matching government dollars with the tremendous development agenda described here.

I am encouraged also by Dupont and Monsanto's comments regarding their work with international centres such as CIMMYT and the World Vegetable Centre. Although such large companies often have relatively small interests in Australia, it is in everybody's interest to develop technology and help build capability. If we, too, interact internationally, our own research system will benefit.

We will need to discuss *how* to optimise these R&D interactions. We have a range of domestic industry structures, and the role of firms participating in our public–private partnerships varies across commodities. Large sections of the value chains are subject to policy development across a range of government portfolios. We need a whole-of-government response embracing not only R&D but climate change, education, health, defence, energy and so forth, with linkages to relevant scientific developments.

Our research community — for example the Academy of Science and the Academy of Technological Sciences and Engineering — is separately looking at internationalisation. We have world-class science in fields that are critical to global food issues.

So if there was one action arising from today, perhaps it should be to suggest to the minister that there is a real role for a forum where bodies such as ACIAR, the corporations and the academies came together to discuss how to optimise our joint and several activities for both national and international benefit.

Conclusion

As our speakers have responded to these questions from the audience, and during the presentations throughout the day, we have had the chance to experience comprehensive thinking about how we are going to address the great challenge of world food security. A clear message is that the public and private sectors must work together to meet that challenge.

Sir John Crawford Memorial Address

THE HON. BOB MCMULLAN MP
PARLIAMENTARY SECRETARY FOR INTERNATIONAL DEVELOPMENT ASSISTANCE

It is an honour to respond to the invitation from the Crawford Fund to speak to you this evening to honour the memory of Sir John Crawford.

Sir John Crawford

2009 marks the 25th anniversary of the death of Sir John Crawford, a remarkable Australian who contributed at the highest levels to the development of Australia and other countries, and was a passionate supporter of international agricultural research for development.

I first met Sir John in 1975 as a (young) member of the first Advisory Board to the Australian Development Assistance Agency, which he chaired. He was an impressive and inclusive leader. Knowing of his extensive national and international experience and his standing, it was a daunting task for a young activist to debate these issues with him.

Writing about Sir John, Bruce Miller[19] characterises him as a man reaching out for humanitarian goals and possessing a genuine desire for social and economic betterment. He saw Australia's future as a trusted and equal partner in our region, rather than a dominant colonial, mercantile or military force. He envisioned Australia as a source of principle and fairness in building new institutions for a global world.

He also cared deeply about the state of the post-war world, a third of whose citizens lived in abject poverty and hunger — and he feared the consequences if this continued. Eschewing the old paternalism, he helped to hammer out the new global model of aid based on the concept of 'partners for development', in which countries work side-by-side to solve development problems.

His very modern approach marks Sir John as a man ahead of his time.

Sir John was also central in the establishment of the Consultative Group on International Agricultural Research, whose International Agricultural Research Centres spearheaded the Green Revolution.

The Green Revolution

Although it has its critics, the Green Revolution was perhaps one of the most remarkable of all human achievements across history. It was an extraordinary display of a small group of people pulling their weight in time of difficultly. For the first time countries came together across the world in a global endeavour to try to end hunger, reduce poverty and the needless deaths of thousands, mainly children. And their success was truly remarkable:

BOB MCMULLAN was sworn in as Senator for the Australian Capital Territory in February 1988, and went on to serve as a Cabinet Minister in the Keating Government, including a period as Minister for Trade. Following a redistribution in the House of Representatives, he stood for the seat of Canberra in 1996 and was elected and served in various shadow portfolios. Following a further redistribution in 1998, he became Member for Fraser, a position he holds today. As Parliamentary Secretary for International Development Assistance, he oversees the implementation of Australia's international development policy and is responsible for the day-to-day management of issues related to the aid program. This involves working closely with AusAID, the Australian Government agency responsible for international aid, international development partners, other donor governments and international organisations to advance Australia's development objectives.

- The proportion of the hungry in the global population was more than halved.
- Staple crop yields in developing countries rose by around 150% thanks to this extraordinary and selfless feat of scientific collaboration and agricultural enterprise.

Yet few, if any, of the quiet heroes who achieved these remarkable achievements are household names.

Perhaps the best-known is the late Dr Norman Borlaug, one of the creators of the high-yielding wheats that are said to have since nourished more than two billion people. Dr Borlaug passed away only last month aged 95 leaving, as his legacy, 80 million hectares of high-yielding disease-resistant wheat crops.

Yet in 1968, as starvation gripped the Indian subcontinent, American academic Paul Ehrlich wrote in his book *The Population Bomb*:

> The battle to feed all of humanity is over. In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate ...

But Norman Borlaug and his colleague, the eminent Indian crop scientist M.S. Swaminathan, had other ideas. By 1974, barely six years after they helped to distribute the CGIAR's high-yielding wheat and rice varieties, India was meeting its own food needs and global hunger was in retreat — perhaps for the first time in history.

The power of partnership between the world's richest nations and its poorest to successfully address urgent and deadly challenges was proven beyond doubt. The power of partnerships in agricultural science to roll back the tide of poverty was demonstrated: it was scientists like Borlaug and Swaminathan who fed the world.

A new challenge

If we are to achieve the Millennium Development Goals we need to return to that priority, to that partnership approach, and to mobilising the power of science together with sound economics to lift agricultural productivity.

In his acceptance speech for the Nobel Peace Prize in 1970 Norman Borlaug sounded a warning:

> … It is true that the tide of the battle against hunger has changed for the better … but ebb tide could soon set in, if we become complacent …

In the months before his death, he constantly repeated this warning to all who would listen, and the evidence is before us that his fears have been realised.

Recent events have shown the tide can turn quickly. In 2008, amid general complacency over world food security and some of the lowest real world food prices in human history, a food crisis seemed to erupt out of almost nowhere. The number of hungry people worldwide, which had been falling steadily to around 800 million, again surged to over a billion. Food prices soared, especially for rice in Asia. While the experts still argue over the precise contributors, primary factors include:

- drought in many growing regions, including Australia
- soaring farm fuel and fertiliser prices
- historically low world grain stocks
- the diversion of food crops to biofuels in the US, Europe and South America.

Some of the factors that caused the crisis have since dissipated: the ensuing economic crash brought down oil prices, while grain harvests have improved somewhat. But for the poorest of the world's poor, the problem has not gone away and global food security remains precariously balanced. In fact, all the signs suggest that the long-term trend for global food prices is for continuing increases and therefore continuing pressure on opportunities for the poor and disadvantaged in developing countries.

As Borlaug and others had understood and warned, powerful constraints were coming into play. These forces have profoundly altered the global food outlook from one of surplus and security to one of uncertainty and risk. They have changed the mood from one of complacency to one of concern. Large forces are now bearing down on the global food supply.

The human population will climb to 9.2 billion in 2050 and continue to rise thereafter. This trend, together with increasing living standards and consequent dietary changes, has generated serious upward demand pressure. This coincides with serious pressures on the supply side, for example the emerging global water crisis. City demand for

water has overtaken agricultural demand for the first time in history. Groundwater levels are falling in almost every country. There are signs the world's major grain-bowls are drying.

The global area of good food-producing land is shrinking. Cities and non-food uses are taking over the world's best farming land. The area of land affected by erosion and degradation has almost doubled in the past twenty years to 24% of the world's land area. Fertile, low-lying river deltas are at risk from accelerated sea-level rise.

At present, biofuels often compete directly with food for agricultural land and resources and, according to the World Bank, this greatly affects food prices. There is growing uncertainty over what energy sources we will use to grow and transport the world's food by the mid-century.

There has been a worldwide decline in agricultural R&D, in both developing and developed countries, including Australia. The impact of this can be seen in declining rates of yield increase in the main food crops. The CGIAR is receiving funding similar, in real terms, to what it received in the mid-1970s — when the world had only half the people now present.

Taken together, these factors constitute a 'perfect storm' for world agriculture. We are now in a situation where the world's farmers must almost double their output of food — using less land and less water, amid increasingly scarce supplies of fertiliser and energy, with limited technology, in the teeth of an uncertain climate. It is a challenge just as great as the one faced by the leaders of the Green Revolution half a century ago.

As Norman Borlaug feared, the world has been lulled by complacency into neglecting the one thing we can never afford to ignore: the need to put sufficient food on the table, sustainably. The magnitude of this challenge was debated in Rome only last week, where a high-level expert forum was hosted by the FAO on how we feed the world in 2050[20]. Here evidence was presented that agriculture's share of overseas aid has declined, globally, from over 17% in 1980 to just 3.8% or less today. It underlines how agriculture has receded on the international agenda: how we have lost sight of the role of food in securing stability, peace and prosperity. It accentuates the prescience of Norman Borlaug, who saw this coming almost 40 years ago.

An essential response

Investment in agricultural productivity needs to increase – and quickly. The areas identified as most in need of this investment are:

- agricultural research and development
- sectors strongly linked to agricultural productivity growth, such as agricultural institutions, extension services, roads and ports, and power, storage and irrigation systems
- non-agricultural investment with positive effects on human wellbeing, like the reduction of hunger and malnutrition, including education — particularly of women —, sanitation and clean water supply, and health care.

Many of these investments can only be made in the public sector. They alone, however, will not solve the problem. There needs to be equally extensive investment by the private sector, including by millions of farmers and their suppliers around the world — but the private sector will not invest unless it is profitable to do so.

In the modern parlance, we face a 'wicked' dilemma in that agriculture, worldwide, is not sufficiently profitable to generate the investment needed to secure the global food supply to the mid-century and beyond. We need to transform the evident need into effective economic demand. We have to devise new and better ways to encourage such investment, or it will not happen.

Of course as a first step we need to free up world trade, as Australia has advocated for decades, in order to allow food production to flow to the most efficient places and producers, and to allow supply to respond to the change in demand pressures.

Australian contributions

Australia remains wholeheartedly committed to the task of feeding the world sustainably, sharing the burden and raising investment levels in agricultural research for development. We were among the scientific leaders in the Green Revolution. Our scientists have staffed and led many of the international research centres at its heart. They continue to lead today.

Through ACIAR and AusAID we will fund and support the goals of food security, poverty reduction and stability. We are already increasing our commitment. We will continue to do so.

[20] http://www.fao.org/news/story/en/item/36193/icode/

Like Sir John, we recognise that poverty, the loss of food security and resulting instability are among the primary ingredients in failed states. We understand that the impacts of state failure reverberate far beyond the borders of the country affected — as waves of desperate migrants and refugees; increases in military, terrorist and criminal threats; risk of disease; disruption to trade and travel; loss of critical resources.

Just last week, 25 years after the world rushed to limit the fallout of a major humanitarian crisis in Ethiopia, we heard reports that Ethiopia is again facing famine as a result of a severe drought. While we cannot make the rains come, we can help communities break the cycle of devastation by equipping them with the tools they need to be prepared for these disasters. With irrigation, grain stores and wells, drought-prone communities like those in the Horn of Africa can survive and prosper.

Australian projects

Australia has particular experience in adapting agriculture to harsh climatic conditions. Our expertise in this area has led to a number of successes in the aid program. Let me illustrate with an example of what we are now doing.

In Timor L'este a survey of subsistence farmers by Australian aid workers found that no family had sufficient food staples of rice or maize to last a full year — all families were forced to ration their food for a period of one to six months a year.

Australian aid is reversing this situation by introducing crop varieties better suited to local conditions and which yield more than current types. Working with CGIAR Centres, the Australian aid program procured a number of staple crop varieties from the region that were suited to the agro-ecological conditions in East Timor. As a result of this 'Seeds of Life' program, food security is improving in East Timor and through it, social and political stability.

In addition, the 2009 Federal Budget allocated $464 million to an initiative called 'Food Security through Rural Development.'

This, on a broader scale, aims for the same results as those in Timor L'este — lifting agricultural productivity in developing countries by improving the way markets function, to build livelihoods and incomes for the rural poor.

There are other elements to this — governance, property rights, division of labour — but where there is an absence of surpluses there are no markets. Without surpluses and markets, assets cannot be built up, credit is almost impossible to obtain and poverty is endemic.

Partnerships

This brings me to the central importance of public–private partnerships in solving the problems of feeding the world. We need partnerships and alliances between government, the private sector and its companies, both large and small, for food production to flourish.

In addition, while the private philanthropic sector has long been involved in global food issues through the vision of the Rockefeller Foundation and other similar institutions, the field has been reinvigorated by the advent of Bill and Melinda Gates Foundation. To put the scale of the Gates' contribution in context, if they were a 'country', they would be the sixth largest donor to the CGIAR and international agricultural research in the world.

We need partnerships and alliances at all levels to deliver good science to the world's 1.8 billion farmers as rapidly, widely and effectively as possible, on a sound economic basis.

Some Australian examples

Not all private-sector activities are on a grand scale: some of them interact with public-sector aid delivery. Recently the Australian Centre for International Agricultural Research commenced a project working with Botanical Resources Australia to re-commercialise the pyrethrum industry in Papua New Guinea. Pyrethrum was introduced to PNG in the late 1950s, becoming a major highland industry employing as many as 80 000 people by the late 1980s. Local products were sold to a processing factory with marketing undertaken by the factory owners. When this factory closed demand disappeared, curtailing the industry.

Botanical Resources Australia, based in Tasmania, saw an opportunity to buy the PNG crop and help re-commercialise the industry. What BRA lacked, however, was knowledge of the local environment and the basis for establishing an agricultural crop to redevelop the industry — areas of expertise for ACIAR. The resulting project is working to introduce planting materials and improved agronomic practices to help with

the adoption of improved production and plant physiological factors.

Another example of ACIAR interacting with commercial business is a project linking with Mars Symbioscience. The project teams up researchers from La Trobe University and the University of Sydney with Mars Symbioscience to select varieties of cocoa resistant to the diseases limiting production in Indonesia's Sulawesi province and to test them in farmer fields.

Mars Symbioscience, which is making a significant financial and in-kind contribution to the cocoa program, has a long-term commitment to improving the environmental, economic and social sustainability of the cocoa industry in Sulawesi, from which it obtains cocoa.

The private-sector role

Where the private sector is engaged with producers in the developing world the imperatives to increase production are great. Such projects demonstrate that business and public-sector aid are viable companions. They are examples of development assistance and good science generating supply to respond to private-sector demand.

There are other innovative ways of engaging the private sector in the development task which are or might be applied in the agricultural sector.

Aid to assist private-sector infrastructure initiatives and investment is achieving some interesting results and generating lessons for us all.

Purchasing food in the country where the World Food Programme has operations has been policy for many years. The WFP's 'Purchase for Progress' initiative builds on local procurement and takes it a step further. It enables smallholder and low-income farmers to supply food to the WFP's global operations, gaining a sustainable economic benefit. The voucher and cash transfer programs allow the World Food Programme to address hunger when food is available but people are unable to afford it, and at the same time provide a financial stimulus to the local economy and a market for local farmers.

Australia provided $5 million to the World Food Programme's relief operation for Zimbabwe for food assistance to vulnerable groups. Food was sourced through a regional tender. Through the participation, for the first time in over a decade, of Zimbabwean suppliers, the process assisted the rebuilding of the country's devastated agricultural sector.

The African Enterprise Challenge Fund is a $50–$100 million private-sector fund backed by some of the biggest names in development finance, and it is hosted by the Alliance for a Green Revolution in Africa. It is a competitive fund that is open to all countries in Africa with the aim of encouraging private-sector companies to compete for investment support for innovative business ideas.

Australia is currently working with the Africa Enterprise Challenge Fund (AECF) to design and implement an Australian Government funded Zimbabwe-specific window to the AECF.

Following a positive design mission undertaken in August of this year, it is anticipated Australia will contribute $5 million to the first round of the competitive selection process of the Zimbabwe 'window' in January 2010, aimed at rehabilitating and reinvigorating agri-business and rural finance for the benefit of the rural poor.

Australia has developed a similar concept in the Enterprise Challenge Fund (ECF) in our region which is showing promise in several areas, including agriculture. The ECF provides grants of between $100 000 and $1.5 million, on a competitive basis, to business projects which directly benefit the poor. To secure funding, projects must also act as a positive model for other businesses to demonstrate the mutual benefits of working with the poor.

The ECF currently funds 24 projects in eight countries, benefiting over 900 000 lives throughout the Asia Pacific region through improved employment and livelihood opportunities and greater access to goods and services from the ECF. The Nature's Way Cooperative, based in Fiji, is a good example of the ECF in action. Established in 1995, the Cooperative undertakes mandatory quarantine treatment on behalf of Fiji's fruit export industry to allow 120 small-scale Fijian growers and exporters to access export markets. From an initial grant of $264 000 from the ECF, it is anticipated the value of the Fijian export market will grow to seventeen times its size and directly employ an extra 1000 Fijians by 2012.

Another emerging area the Australian aid program is keen to explore is the idea of Advance Market Commitments (AMCs). AMCs are a way to deliver proprietary high-tech products like vaccines to countries and consumers who cannot afford them. They are public–private partnerships that tackle the inequity issue without reducing the

incentive to companies to develop new technologies and products that save and improve people's lives.

AMCs have proved a successful way of encouraging funding and research into cost-effective treatments and quality treatment of diseases that are particular to or prevalent in the developing world. They provide a legally binding commitment by donors to fully or partially finance the purchase of vaccines at a specified price, with a ceiling set on the maximum quantity of vaccines that will be subsidised.

A pilot AMC to tackle pneumococcal disease, launched in February 2007, is expected to prevent up to 5.8 million childhood deaths by 2030.

So far AMCs have been confined to pharmaceutical development, but there is scope to expand the principles that underpin their application into new and important areas. What if we could use AMCs in order to develop technology that has the potential to revolutionise agriculture in sub-Saharan Africa? Or to improve and develop drought resistant and higher yielding crops? Or medicines and methods to improve livestock production?

Australia has indicated our interest in contributing to future AMCs in the health sector.

I hope that following discussions that I have had with the Crawford Fund, and associated discussions over the past few days, we may find a way to apply the sound economic principles underpinning this initiative to the vital task of enhancing agricultural productivity. The AMC approach represents an evolution of the 'partnership for development' Sir John envisioned. It combines the expertise and innovation of the private sector with public sector goodwill and, perhaps most importantly, financial backing.

Conclusion

We have made significant steps toward changing the way our development programs operate. We have had some difficulties, but these are far outweighed by our successes.

This is not a reason for complacency. We must do more, try harder and broaden and hasten our efforts. We must be more audacious in what we undertake. Ours is a time of great difficulty and challenge.

The combined effects of the global financial crisis and climate change have the potential to undo the significant progress we have made in reducing global poverty. We are compelled to continue to pull our weight, and we will. We will do so because it is the right thing to do. We will do so because it is the smart thing to do — a hungry world is a dangerous world; an inequitable world is an unstable world.

For many, freedom itself begins with an end to poverty — and ending poverty begins with the ability to satisfy our universal need for food.

The UN World Food Program

JOSETTE SHEERAN[1]

World Food Program
Rome, Italy

The United Nations World Food Program feeds on average about 90 million people per year, two-thirds of them children. It has offices in 80 countries. Despite the scale of this effort and the large quantities of food involved, forward planning is very challenging because of the small financial reserves on hand at any time. Natural disasters and conflict generate unpredictable demand for food. The WFP is evolving successful strategies to address not only immediate needs but underlying causes of food crises; partnerships have a significant and essential role in this success.

Introduction

It is not only an honour to be here but a great opportunity to talk about issues of mutual interest. I actually came here to do something very simple but which maybe we don't do often enough: to thank the people and government of Australia for their leadership on food security. So when I met with the Foreign Minister I told him how wonderful Australia is, and of the meetings you have had this week; he agreed that these do provide special opportunities. A number of my heroes are here, some known to me only by name and others whom I have met — Bob McMullen, Jim Ingram and others that follow in the great traditions of Sir John Crawford, Norman Borlaug and others who really understood the power of advances in farming and food science and technology to save lives and to bring a more secure, humane and peaceful world. Australia has had a key role in founding CGIAR and through ACIAR, institutions that provide innovation and leadership in ending hunger in areas of the world, and particularly Africa, where progress has been slower than we have wished.

JOSETTE SHEERAN has been Executive Director of the United Nations World Food Programme (WFP), the world's largest humanitarian organisation, since April 2007. Previously she served as the United States Under Secretary for Economic, Business and Agricultural Affairs in the State Department. She had earlier held senior positions in private sector management and as a journalist. She holds a BA from the University of Colorado.

The challenge

I was unable to attend the presentation two weeks ago in Iowa of the World Food Prize to Dr Gebisa Ejeta of Ethiopia, whose sorghum hybrids resistant to drought and the devastating striga weed have dramatically increased the production and availability of one of the world's five principal grains. I had been given a great honour of delivering a memorial speech about Norman Borlaug's legacy when a suicide bomber attacked WFP's headquarters in Pakistan, killing a number of our staff who had been maintaining the humanitarian lifeline for up to ten million people in that country, including three million displaced by the conflict there. This event was really symbolic of the convergence of our worlds: hunger, food insecurity and violence on the world's front pages, while you are working to beat the clock on food supply for an expanding global population in a more severe and erratic climate.

I really want to commend the work of the Crawford Fund's World Food Crises Task Force, and in particular Jim Ingram. The report[2] of the

[1] The text here was prepared by the editor from an audio recording of the presentation.

[2] 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, ATSE, Melbourne, 60 pp.

task force noted the intersection of research investments, trade and aid in helping ensure that we can feed a hungry world. The report reminded me of the vulnerability that we experienced a couple of years ago during the food crises that exposed areas in the global food supply chain that we have to really shore up. We saw that whole nations could not procure supplies on global markets (and the World Food Program could not get tenders filled), while others resorted to shutting borders and banning export of even humanitarian food.

These events illustrated the urgency of addressing anew the issue of adequate food supply and adequate access by the world's hungry. The first Millennium Development Goal, which includes the goal of cutting the number and the proportion of hungry in the world in half, is the most threatened. In just the past two years over two hundred million people have been added to the ranks of the urgently hungry. At the recent G8 and G20 meetings, world leaders put food security front and centre of the global agenda. We must not take food security for granted. In the developing world, including 80% of the countries in Africa, prices for essential commodities are higher today than they were a year ago. What that means is that people in many places can afford only two-thirds as much food today as they could just two years ago.

This is urgent business. The World Food Program is very honoured to have been created by the world as a member of the United Nations family to help nations when all else fails and to help them build secure food supply systems that will reduce their vulnerability to emergencies and disasters.

The World Food Program and Australia's contribution

Ours is not grandmother's food aid. Eighty percent of the food that WFP purchases now is purchased from farmers in the developing world; this huge shift allows us to build synergies between even emergency action and alleviation of the root causes of hunger. For example, we tripled our local purchases in the Democratic Republic of Congo in the midst of a conflict so that farmers who could not get their food out were supported and did not require food aid. Farmers would much rather sell their food if they can connect to a market, even in the midst of conflict.

An announcement was made today that Australia will generously provide predictable multiyear funding for the WFP[21]. I met recently in London with a number of experts on global supply chains from Unilever, Cadburys and military food services who commented that WFP is the most complex supply chain in the world. We have to reach places like Darfur and there feed four million people a day in the middle of hostile deserts that have no roads. The people I spoke with thought of lead times of three years. I said, 'what if you didn't know how much money you would have in twelve weeks'? They replied 'That is impossible'. The world's most complex global supply chain does need pre-planning, pre-positioning, pre-contracting and pre-buying.

Unfortunately less than 4% of WFP's money is multiyear predictable so that we can plan ahead. When I described this great difficulty to the Prime Minister Mr Rudd he said, 'Lets change that'. So thank you Bob McMullen and all those who helped with the leadership and the report that the Crawford Fund put forward; the result has been wonderful. It allows us to get ahead of the hunger curve and, even in places like Afghanistan, to buy wheat from local farmers so that when we are filling the cup for the schoolchildren we also support the farmers who so desperately need an outlet for their food.

It also means that the WFP can ask a number of questions: not only whether people are hungry but why they are hungry: what is the basic problem? I want to thank Dr Pingali and the Gates Foundation and others who have worked with us to get better at our vulnerability analyses. In the old days these were just crop assessments. Fortunately when the food crises hit we had actually considered other factors such as differential inflation between food prices and wage prices. That is what hit the developing world two years ago. Food prices galloped ahead, doubling and tripling, while for eight or twelve months wages stayed flat and therefore the bottom billion people could afford a third less on a budget that was already devoted entirely to food. So partnerships are really valuable.

Examples of projects with multiple benefits

We would like help from experts like you and others throughout the world to develop connected, longer-term solutions to problems of hunger and poor nutrition. The following are some examples that could be built on.

[21] http://www.foreignminister.gov.au/releases/2009/fas091026.html

Developing local foods

The World Food Program conducts school feeding programs — school lunch programs — for 20 million children. This is not permanent charity. It helps countries build up a food security net that can be handed over to others, as we have now done in over 30 countries. Typically it is filling one cup with porridge each day for each child; that is the only food the children know.

After the recent food crises the President of Liberia told me they import up to 80% of their food. The president wanted to fill this cup with local produce, although the children had lost their taste for it. The local cassava and maize offer an opportunity to produce farina and thereby to re-introduce the population to their own food products. I have pledged to assist, but we need help in the task. WFP is not an expert on how you increase production. How do you scale it up? It would be a big pull factor if we could buy that food locally. That is where we need FAO, that is where we need the Gates Foundation and the Rockefeller Foundation as partners, and the work of CGIAR and all of you. What kinds of technology? Where does it make sense for Liberia to rebuild? And, guess what, there are virtually no nutrients in that farina. Do we fortify it? Do we plant better seeds? We need partnerships to address these questions. If we can fill this cup locally we will change the taste of a generation and strengthen local markets. I can foresee the day we would step out; there would be no need for aid. There is good business in helping to feed the schoolchildren of Liberia.

In Afghanistan we are at a point where we can dream of buying more wheat locally. We do it to a small degree now with the help of Australia, Canada and others, and we have biscuit factories where women are producing fortified biscuits for schoolchildren. Again this doesn't need permanent aid.

The multiplier effect

A second example I will give is from Senegal. We now buy locally whenever possible. Senegal is a food-deficit nation, but they do have a lot of salt. For a micronutrient initiative with Canada and others, salt is purchased from seven thousand village producers, mostly women, who never had a secure outlet — the first win. Now these women, for the first time, are iodising the salt because Senegal has an iodine deficiency epidemic. Because they have a guaranteed contract, the producers could get the equipment to add the iodine and now iodised salt is being sold in those villages — a second win. The third win is that the women are helping their own country by rebuilding areas that have been devastated. A fourth win is that the children are getting the food and the iodised salt they need. So a single initial investment has transformed whole communities. We need help in really understanding how to do this in other situations. The World Food Program does not know how to iodise salt. We don't wish to do that, but we do need the partners to do so.

Convenient, non-perishable food

In regions of increasing floods and droughts, the populations of many nations like the Philippines sometimes have no access even to adequate clean water for long periods. Neither the WFP nor the people have food products that can ensure that young children's minds and bodies stay strong through such challenges.

The World Food Program, with the help of Australia, a food technologist and others, has developed in India a sweet, highly fortified paste made with chickpeas and dried milk. If a mother rips off the corner of the package of the day's ration, the paste can sustain a child with all the necessary micronutrients without adding water — and it needs no refrigeration.

Every leader in the developing world to whom I describe this example — Prime Minister Meles, President Arroyo, others — recognise that they need such a product. Prime Minister Meles said that in a drought in Ethiopia there is nowhere for a parent to turn even if they have money. We are developing such products now in Pakistan. In the Philippines we may be able to use a coconut base. We will do our best, but how to connect the crops with accessible, non-perishable food for the bottom billion people?

We currently have a global call for every high-energy biscuit that we can find for use in the Philippines. These are biscuits produced by WFP; fortunately Thailand, Ecuador and others now produce their own. In Egypt we make a date bar that is packed with nutrients; when troubles hit Gaza last year, people had no cooking fuel, no electricity and no water. Hospital staff couldn't eat, patients couldn't eat. We produced twenty million of those date bars after gearing up overnight — talking to the government and asking DSM (an international life science and performance materials company from the Netherlands) to tell us how to fortify them to suit the people in Gaza.

Other appeals for help

The arrangements described above are very ad hoc. I envisage progress that within five years will provide people in the developing world with tools to give them affordable access to emergency foods based on their local produce. We need to know where all the production capabilities lie — not just those of the WFP. Prime Minister Meles of Ethiopia has asked that much broader assistance than the WFP can provide should be made available. So that is another appeal that I would really like to make.

We are working very closely with the Gates Foundation, the Howard Buffett Foundation and the Rockefeller Foundation to examine the ways we contract with farmers. WFP — whose budget was $1.4 billion last year — invests in developing-world farmers by buying food. We are doing this in a way that allows them to plan for and invest in better seeds, better technologies and better access to markets. The great thing about WFP is that we are a real market — a market with patience and a market that can draw on the resources the world has. In our purchasing project, involving 20 nations, we are seeking ways to work even better with small farmers like the salt producers in Senegal and others to support their efforts. We really need the backing of your understanding.

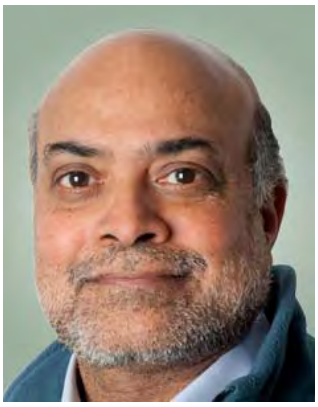
We work very closely with AGRA (the Alliance for a Green Revolution in Africa) to make sure our public–private projects are in the same area that AGRA is working in. In our vulnerability analyses, and also in reducing risk for farmers, WFP is working with Rockefeller to map the areas that are the most vulnerable. We wish to be sure our humanitarian aid is looking at things like disaster risk insurance —we did a pilot project on this in Ethiopia that proved to have market viability; it reduces risk for the farmers who otherwise bear all the risks.

Conclusion

In many of the areas I have described our interests and work intersect. I do want to thank Australia again. In response to a question from Prime Minister Rudd, I emphasised the importance of predictability to help us get ahead of the hunger curve. His response three months later was very welcome. I know that such a rapid response has required a lot of political support, and support from AusAID and others.

By my estimates, leaders such as Sir John Crawford and Norman Borlaug have saved more physical lives then any human being in history. Theirs is a great legacy and a great goal to keep in mind, and also a great inspiration.

We are proud and honoured to connect with all of you in your work — solving hunger and its problems at its roots. So thank you.



Reflections, Conclusions and the Way Ahead

PRABHU PINGALI

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This talk reflects on the proceedings of the Crawford conference and provides a way forward in policy thinking. Effective food and agriculture policy decision-making requires clearer differentiation of countries by their stage of development. Operationally, it implies different approaches at the country level based on the stage of development. It requires concerted and coordinated efforts from the public and the private sector, and the international donor community. The Bill and Melinda Gates Foundation has committed itself to addressing the problems of chronic hunger and poverty in the least-developed world and for marginalised people in the emerging economies. The talk also provides information on the approach taken by the Foundation in agriculture development.

Introduction

This is my first 'after-breakfast talk'; to do this in the splendid surroundings of the Australian Parliament house makes it even more significant. Thank you, Crawford Fund, for inviting me to do this.

DR PRABHU PINGALI is Deputy Director of Agricultural Development at the Bill and Melinda Gates Foundation. He was formerly the Director of the Agricultural and Development Economics Division of the Food and Agriculture Organization of the United Nations. He has three decades of experience analysing food, agriculture and development policy in Asia, Africa and Latin America. He has worked at CIMMYT, IRRI and the World Bank's Agriculture and Rural Development Department. He is a Foreign Associate of the US National Academy of Sciences, a Fellow of the American Agricultural Economics Association and was President of the International Association of Agricultural Economists 2003–2006. Prabhu Pingali has authored ten books and over 100 referred journal articles and book chapters.

I would like to do two distinct things this morning: to reflect on the great presentations and conversations that took place yesterday, and to brief you on the Bill and Melinda Gates Foundation and what we do.

Yesterdays presentations

Yesterday provided a panoramic look at the broad issues around agricultural development and food security — where we have been and where we need to be. It is opportune to have this conversation today, because even two or three years ago you would not have seen the present level of interest in or excitement about global agriculture and food security issues.

It took a food price crisis and a financial crisis to remind us that there are over a billion people in the world who are hungry. It took financial and a food crises to remind us that more than 1.5 billion people are living with less than a dollar a day, and as Dyno Keatinge reminded us more than 2.5 billion people are malnourished.

Meeting the food needs of a growing population in the developing world continues to be the major global food policy challenge. Will we be able to feed the world in 2050? How are we going to do this? Phil Pardey pointed out the long-term productivity stagnation, and in some areas, decline. We faced these challenges in the 50s and 60s and we overcame many of them.

What's new today is that there is not just one developing world, but many different ones. Problems are typically characteristic of particular countries and their individual stages of development. We need to be much clearer in stratifying countries by their stage of development and identifying solutions relevant to a particular stage

of development. For this talk let us consider two sets of developing countries: the least-developed countries; and the emerging economies.

Many of the least-developed countries are in Sub-Saharan Africa. These are countries where chronic hunger and chronic poverty persist despite all the efforts that have been made to increase productivity, to provide technology change and to change policies. These are countries that face the chronic problems associated with agriculture development: poor infrastructure, poor access to markets, lack of technology and R&D, poor human capital infrastructure and so on.

We need to identify the right solutions to address the problems of these countries. In some cases this may mean going back to where we were in the past to identify the productivity solutions that were created by the original Green Revolution. How can these be adapted to new environments and new social, economic and agricultural conditions? And learn from the mistakes that were made in the original Green Revolution and correct those mistakes? The work of the Alliance for a Green Revolution in Africa (AGRA) is exemplary in this regard (http://www.agra-alliance.org/).

The other set of developing countries are the so-called emerging economies. Here you see a lot of dynamism: rapid economic growth, rapid urbanisation, growth of the middle class, diversification of diets and a whole set of modernising changes taking place. In these countries you still have to invest in agricultural research and development, but it needs to be very different. The research focus in these countries ought to be one of primarily looking at how to sustain the productivity gains that have been made over the past 50 years; how to break away from stagnation in productivity; how to shift to a higher plateau of productivity for the basic cereal crops. At the same time, ways to commercialise and diversify smallholder agriculture to meet the demands by urban middle-class populations for a diversified diet are needed. We need to create sustainable links between smallholders and the supermarket systems that are exploding across urban areas. These are very different but extremely important challenges.

Across these two sets of countries at the ends of the spectrum, however, there are some common problems. An obvious common problem is that of climate change.

How do we handle climate change, and the resulting increases in vulnerability of the poorest populations, across the developing world? Over the next decade or two, the problems of climate change and the way agriculture adapts to climate change and is a source of mitigation of climate change will represent significant new research issues. The way we address the problems of vulnerable populations and how they cope with climate change may become the new unifying theme that brings the research communities of the developed world and the developing world together.

An exciting new frontier for all is to create a sustainable source of support for the agricultural research system: an essential system even if there were no burgeoning food crisis. We should all look forward to this task.

The main focus of the conference yesterday was a focus on the private sector. Which private sector, where?

A private sector that is crucial in development is the home-grown private sector around input and output markets, around rural services that provide credit and other financial services. Small private-sector operations are becoming increasingly stronger in the emerging economies of the world, but continue to be very weak in the least-developed countries. This is the private sector that we must focus on, especially on getting rid of some of the existing market failures: high transaction costs associated with poor infrastructure, poor communication facilities, poor legal environments, poor regulatory environments, etc. Unless the public sector gets its act together to provide the basic business climate that the private sector can operate in, there will be little movement of the sector into the markets in rural areas.

The second important private sector is the multinational private sector that is increasingly involved in agricultural R&D. It is now putting far more resources into agricultural R&D than the public sector — but unfortunately the R&D done by the multinational private sector does not address the needs and the problems of the poorest people in the poorest countries in the developing world. This is another type of market failure.

How do you get the technological advances that can make a huge difference to the ability of poor developing-country farmers to cope with drought, or submergence, or various pest problems? There is enormous knowledge and technology already available but not applied. That's the market failure that needs to be addressed and that's where the

public sector — in the countries concerned but also the international public sector such as the CGIAR system — needs to get involved to break the market failure barrier that exists.

In the more emerging economies you see a very different scenario: here the private sector is moving very rapidly into agricultural R&D. Sometimes the enterprises are home-grown companies, sometimes multinationals. My own country India is having fairly rapid growth in private R&D. The private R&D work going on in the emerging countries is of high quality, equal to what you see anywhere else. The work, however, is necessarily focussed only on areas where it makes commercial sense for the company. It is not surprising that Bt cotton is spreading rapidly across India, but that is the only major biotechnology product to do so. What about rice, what about wheat and maize, crops that are crucially important to the poor people? There is not much investment, and this again is where the public sector needs to come in to underwrite some of the costs of making those investments; we don't have good models yet. A challenge is to devise effective models for public–private partnership.

Another challenge is associated with the growth of supermarkets. For a long time this has not been taken seriously. It is happening very rapidly. In the last five years the number of supermarkets within a one-mile radius of my house in Hyderabad in India has gone from zero to ten. The same thing is happening around the developing world, and one of the big opportunities for smallholder agriculture is to link into these supermarkets to grow themselves out of poverty by supplying the supermarkets chains.

Unfortunately the transaction costs for smallholders linking into supermarket value chains are enormous. We need to figure out mechanisms by which smallholders can participate in the supermarket revolution — to devise regulatory and contracting systems to ensure that high quality and safety standards are met and that diversity is fostered in production.

There is a lot of private-sector interest, but no private operator is willing to make the initial investments needed to get the smallholders into the system. That's where the public sector must come in and bridge the gap by reducing the risks associated with that initial investment.

As we look to 2050, there are huge challenges for enhancing agriculture productivity and improving the lives of the rural poor in the developing world — possibly larger than the challenges we have seen in the past. I am enormously optimistic, however, that not only will we be able to feed the world in 2050, but that we will see a world that is much richer and with a quality of life previously unsurpassed.

The Bill and Melina Gates Foundation

The second part of my presentation is about the Bill and Melinda Gates Foundation.

Most of you are aware of the Bill and Melinda Gates Foundation; it started about ten years ago. It started because of a strong belief of Bill and Melinda Gates that all lives have equal value, wherever they may be, and that it is up to us to ensure that all lives are lived to full potential.

Today we are the largest private philanthropic foundation in the world. When the Foundation started ten years ago, the work was pretty much concentrated on two areas: on health issues around the world such as HIV/AIDS, TB and malaria, and inner-city schools in the United States. The goal in the latter was to bring a much higher standard of education and quality of school life to students.

About five years ago, the Foundation decided that it needed to address problems associated with chronic poverty and hunger if it was going to make and sustain improvements in global health. It was very clear that in addition to providing better medicines and better vaccinations it was necessary to invest in broader development interventions in order to change the long-term quality of life of very poor people in rural areas around the world. That was the genesis of a program in global agricultural development.

Why agriculture? It is very clear: agriculture provides one of the primary opportunities to address the problems of hunger and poverty in the developing world because most of the hungry and most of the poor live in rural areas. If you can increase food crop productivity in rural areas, the first and primary impact is better and more reliable diets for the populations that are growing the food itself. Then, there may be a surplus that can go into the market. The benefits of improved agriculture in reducing poverty are very clear across the developing world. Poverty has been greatly reduced by agricultural development in East Asia, South-East Asia and Latin America.

This evidence encouraged us to seek other areas where success is possible and to invest in agricultural development. Our vision was to focus on smallholder productivity growth as the primary mechanism for reducing poverty and hunger.

We targeted smallholder agriculture in Sub-Saharan Africa and in South Asia. Why these two areas? Because these are the areas where we still see stubbornly high levels of hunger and food insecurity, where hunger and low productivity problems have been persistent despite the decades of high-quality agriculture research that has been done. They are areas that have been chronically poor and where substantial effort needs to be made if there is to be a real change.

Thus we are aiming to have a massive and rapid impact on hunger and poverty in particular areas in particular regions. As we have looked at grant proposals that have come in and as we have talked to our partners, the one question that we have been asking very carefully and very clearly is 'How does the work that you are doing result in a reduction in hunger and a reduction in poverty in Sub-Saharan Africa or South Asia? Can you show us the pathway for that impact? Can you measure your progress along that pathway?'.

It is very important to make the point that the Bill and Melinda Gates Foundation is basically a Seattle-based philanthropic foundation — a grant-making body.

We do not undertake any work on our own. Our job is to identify the best projects that are being done by the best possible partners and to empower them to do the work — and then empower them to make the change that needs to be made.

We have been working with some of the greatest partners around the world, and we are constantly expanding the set of partnerships that we have.

Our most important partner is AGRA — the Alliance for the Green Revolution in Africa, whose great work Namanga described yesterday. We also work closely with CGIAR centres, particularly the centres in Sub-Saharan Africa and South Asia. We have committed close to $500 million to the CGIAR system to date, and our commitment is likely to continue, especially in view of the changes that are taking place in the system now. We have a close partnership with the UN Agencies, especially the World Food Program as described by Josette Sheeran (page 97). In addition we have been working with FAO, UNDP and the NGO community. Members of this community such as Oxfam have been major partners for us, but increasingly we have been working with NGO communities in developing countries.

Two weeks ago I was in Bangladesh and with the NGO BRAC (Bangladesh Rehabilitation Assistance Committee), a major partner in that country. BRAC is starting to become international, BRAC-Africa, for instance, is now becoming a major presence in the market for financial services for the poor.

One of the things I'm doing on this trip to see how we can work together with ACIAR, AusAID and Australian universities. How can we jointly make more rapid progress towards our common goals of hunger reduction and poverty reduction?

How do we work? Within the agriculture program, we've taken a value-chain approach in our grant-making. We make grants at the high end of the science and technology spectrum to bring the best possible science to address the problems of crop improvement, life sciences innovations, etc. in the developing world. Second, we emphasise methods for integrating at the farm level to improve productivity. We are looking at management technologies, better extension systems, better information systems at a farm level, etc. The third part of our strategy is to better connect the increased productivity to markets and improve the markets themselves so that there is a smoother chain linking smallholders to the market system.

Finally we've learnt the lesson from the past that it is not technology alone that is going to make a difference to farmer's lives. If that technology is not put into the context of an enabling environment that allows farmers to enhance their productivity, there will be very little adoption. You need the incentive systems, you need the infrastructure, you need institutional change that is essential. So as a foundation we have invested and will continue to invest significantly in creating that enabling environment, in looking at the policy changes that needs to take place in order to provide farmers the environment for accessing technologies and improving their productivity.

Conclusion

Designing food and agriculture policy is substantially more complex in today's world than it was in the past when relatively closed food economies were the norm. While chronic hunger and poverty continue to be daunting problems in much of the developing world, income growth, urbanisation and global inter-connectedness bring about new policy challenges for emerging economies as well as for the least-developed countries.

Climate change adds to and or intensifies the stresses faced by poor farm households, particularly those in the least-developed countries and the dollar-poor in the emerging economies.

Modern food and agriculture policy needs to be redesigned and adapted to the emerging trends that developing countries are facing while at the same time ensuring that it reflects the stage of the development that the country is in.

The Bill and Melinda Gates Foundation is working to break these cycles of hunger and poverty by providing small farmers with the tools and opportunities to boost their productivity, increase their incomes, and build better lives for themselves and their families. On an annual basis, the Foundation provides grants of the order of $450–500 million for agricultural development. That is a significant contribution from a private philanthropic foundation, but in terms of the real need for agricultural development it is a drop in the bucket.

At least nine billion dollars per year, targeted towards agricultural development, are needed in Sub-Saharan Africa alone. No one foundation can provide this: we need to work together. We need a coherent strategy that brings the bi-laterals, the multi-laterals and the foundations together to address the problems of chronic hunger and poverty in the least-developed countries, and the emerging problems in the rapidly-developing countries.

Australian Private-Sector Investment in Australian and International Agriculture

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It is easy to assume that the public sector dominates assistance to smallholders in the developing world, including in the provision of research and development. These proceedings have illustrated that this is not always the case and that the private sector can and needs to be engaged, even in early stages of agricultural development. In Australia, private-sector investment is low relative to that in many other developed countries. However, over the past two decades we have seen an increase in that investment through a variety of means, including the growth of rural research and development corporations and more recently, in public–private partnerships in plant breeding. This increase has enabled public-sector investment to shift to tackle emerging challenges for the agricultural sector. Both domestically and internationally, these new models of collaboration between the public and private sector are reframing agricultural research.

DR JOANNE DALY is an evolutionary biologist who was appointed Group Executive, CSIRO Agribusiness, in April 2007. She was the inaugural Chair of the Management Committee for developing the *Atlas of Living Australia* and in October 2009 was appointed Chair of the Governing Board of the Global Biodiversity Information Facility. After a PhD at the Australian National University she was a Fulbright Fellow at UC Berkeley. Daly joined CSIRO Entomology in 1983. From 2001 to 2003 she was on secondment to the Australian Government in the area of international relations in science and technology. In 2003 she was head of the National Research Priorities Taskforce. Dr Daly returned to CSIRO as Chief of Entomology in February 2003. In 2003 she received the Public Service Medal.

Introduction

These proceedings highlight the strong support that exists for private-sector investment in agriculture in developing countries. Previous contributors have demonstrated the need for strong partnerships between the private and public sectors to ensure that the whole food value chain is activated: from increasing on-farm productivity to ensuring that surplus food can be transported and stored safely, to the creation of markets.

The challenges ahead to ensure food security for the planet are considerable — food production needs to be doubled by around 2050 in the face of water and fertiliser limitations, restraints on carbon emissions, changing climate and an ever-increasing urban population. Food security has become a focus of governments, driven initially by a spike in food prices reinforced by diminishing food reserves; and now reinforced by changing climate scenarios (Stoeckel 2008; Msangi and Rosegrant 2009).

The traditional view of the provision of assistance to tackle challenges facing developing countries sees this function as the purview of the public sector through national governments or international aid agencies. Such a view is based on the premise that developing countries are in a situation of ‘market failure’. If this view can be questioned for developing countries then it is also worthwhile opening up the same issues regarding the provision of agricultural research and development (R&D) in developed countries. This paper explores some of these ideas in an Australian setting.

There are three issues to consider:

- business investment in agricultural R&D is growing and replacing some public-sector expenditure and this will influence how we respond to food security in the least-developed countries
- Australian overseas investment in R&D is undergoing renewal
- participation by Australian public-sector R&D in overseas agricultural work will be greatly enhanced and produce a more enduring solution if it is done in partnership with the private sector.

Trends in Australian R&D

In Australia, there is good evidence (Fig. 1) that growth in agricultural productivity over the past fifty years has been driven in part by domestic R&D (Mullen and Crean 2006). Yet both in Australia and overseas there has been a persistent decline in public-sector agricultural R&D over the same period. This decline is thought to have negative consequences for agricultural development in the least-developed countries that have relied traditionally on spillover benefits from developed country R&D (Pardey *et al*. 2006a).

A closer look at the data, however, indicates that the Australian situation is a bit more complex, with shifts occurring in the agencies responsible for that R&D. Total investment in agricultural R&D in 2004–2005 was AUD1.4 billion, a 20% increase in real terms since 1996–1997 (DAFF 2008, Appendix A, drawn from Australian Bureau of Statistics data 2006). The biggest change was a reduction in state government investment, falling from 53% of total investment in R&D in 1996–1997 to 38% by 2004–2005. At the same time, universities increased their proportion of the total from 16% to 23% and business investment in rural R&D increased from 8% to 17%. This upward trend in private investment in Australia is encouraging because it is starting from a relatively low base of less than half the level of other major OECD countries (Pardey *et al*. 2006b).

The improvement in private-sector spending may well be a sign of maturity in agricultural R&D. It potentially signals confidence as private businesses believe that they can capture profits into the future. This frees government money to be applied to broader national challenges that threaten the very existence of profitable agriculture in this country. Certainly in CSIRO and in the larger state agriculture departments there has been a shift away from traditional on-farm productivity work towards more modern approaches made

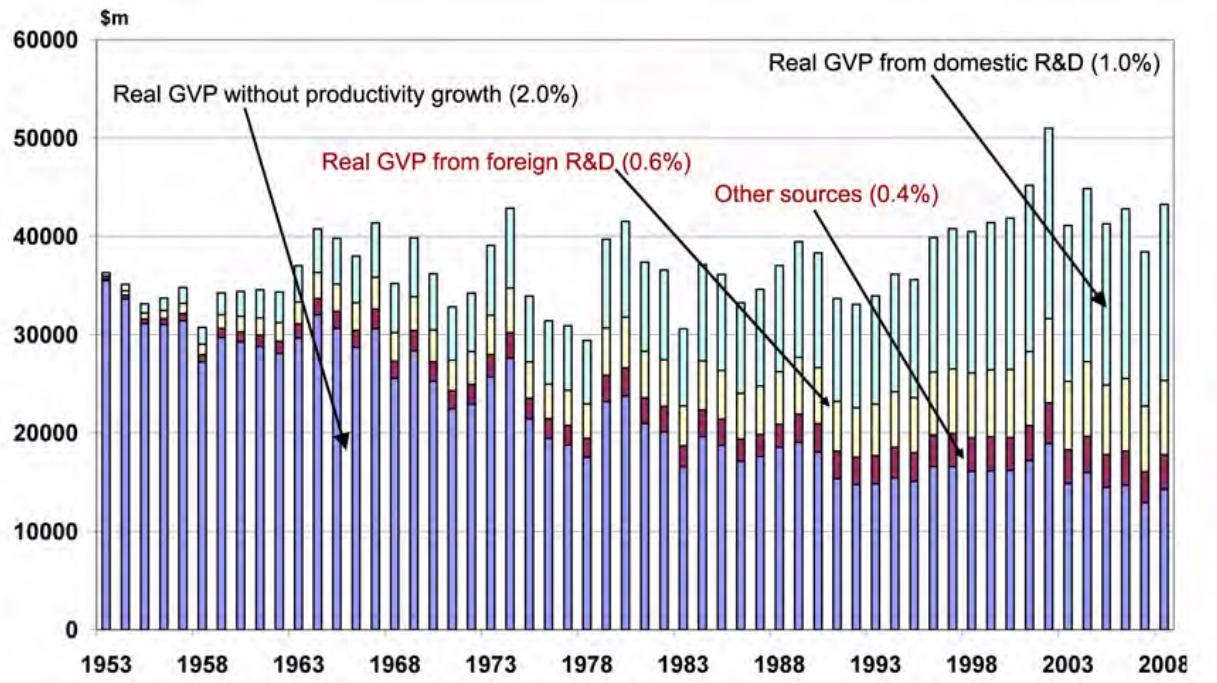

Figure 1. Sources of productivity growth (based on gross value of production) in Australian agriculture, 1953–2008 (Mullen and Crean, unpublished data, 2009; based on Mullen and Crean 2006)

possible through molecular biology. Other resources have been redirected to broader issues of environmental sustainability and the emerging issues around climate change, soil degradation, reduced ground water and restrictions on carbon emissions.

A number of indicators may explain some of the increase in business expenditure, and how it affects how basic productivity work is now funded in Australia:

1. Primary producers contribute private-sector resources through a levy system that underpins the rural Research and Development Corporations (RDCs)

Fifteen rural research and development corporations operate in Australia. The first of these bodies were established in 1989. The corporations are run by industry bodies, and collect levies from producers, based on production. These funds are matched by the Federal Government up to a statutory limit. R&D investments are directed at key priorities determined by the relevant industry and at cross-industry issues determined by the government. In this system, producers can invest their own resources in a collective way to harness and direct government investment in R&D to the benefit of their industry (http://www.ruralrdc.com.au/).

There was a 40% increase in real terms (estimated to be from AUD188 million to AUD267 million, in 2008 dollars) in such industry funds over the period 1996–2008. Most of this increase occurred up to the years during which the RDC model was reaching its full potential. Funds are estimated to have plateaued over the past seven to eight years (DAFF, unpublished data, 2008).

One of the consequences of the long-term investment of public funds in agricultural R&D through this model is that Australian producers have obtained significant additional benefit through leverage of co-investment from research providers. Thus, of the about AUD490 million of new money spent by RDCs in 2007–2008, 45% was government funding (DAFF, unpublished data, 2008). When this money was invested in public institutions, most of it would have been matched with further public-sector investment from the institution. It is hard to get exact figures, but in situations where RDCs are paying 50% of the total cost of the project one dollar of producers' money can leverage up to $3 of government money. In the long term, it can be hard for public research organisations to sustain their core capability and infrastructure in such a co-investment model. Indeed, CSIRO (2008, p. 16) noted in its submission to the *Review of the National Innovation System* (2008) that the co-investment model employed by the RDCs was diverting scarce resources away from strategic research towards more close-to-market work.

2. Aspects of public-sector R&D have been privatised

This has been evident over the past two decades in areas such as stored grains, and in wheat, cotton and sugar breeding. This shift from public to private sector has at times been accompanied initially by a drop in investment in public-sector R&D as the new companies grappled with the reality of making a profit. This was particularly evident in industry investment in CSIRO's Stored Grains Laboratory during the 1990s (J. Daly, unpublished data). Nevertheless, such moves do have the potential to free up public-sector investment. Privatisation of breeding programs allows public institutions to move their efforts into pre-competitive research in breeding.

3. Gradual emergence of private-sector farm advisers in the agrisector

With the reduction of public investment in extension — particularly evident in the cotton industry but also horticulture and the grains industry — private-sector advisers have emerged. This area has a lot more potential to grow, but already in the grains industry almost 50% of growers use consultants.

4. The strengthening public–private partnerships between global life science companies and public-sector R&D in Australia

Such partnerships have a strong focus on basic research in plant breeding using modern technologies. They are common overseas. Recent public announcements include the CSIRO/Bayer CropScience alliance in cereals; and the Department of Primary Industries Victoria/Dow AgroSciences alliance in canola, both of which have been announced in the past six months. In Australian cotton breeding, CSIRO has established strong relationships with trait providers and other IP owners (e.g. Monsanto, Bayer CropScience) to bring important benefits such as Bt insect resistance to Australian growers.

These partnerships are important as they support basic productivity research but with a clear eye to the route to market, allowing both the company and the R&D provider to capture benefit. Specific contractual obligations that protect the interests of Australian producers are characteristic of these alliances.

5. Direct investment by firms into agricultural R&D

This investment complements these public–private partnerships — Australian Bureau of Statistics (ABS) figures indicate private-sector investment of the order of AUD100 million a year (ABS 2009). This figure does not take into account direct expenditure of overseas companies into the Australian public sector.

If we summarise the domestic situation, we can see a gradual rise in private-sector investment through a variety of means over the past two decades in Australia. This increasingly sophisticated arrangement of private-sector investment provides a strong backbone that builds on strong institutional public-sector funding. In particular, we are seeing an increased investment in breeding and productivity work by the private sector as these are areas in which the potential for value capture is among the greatest.

Australian investment in overseas R&D

Australian overseas investment in agricultural R&D is undergoing renewal. In May 2009 the Australian Federal Government announced a new $460 million program, 'Food Security through Rural Development', to be delivered by its lead development agencies, AusAID (the Australian Agency for International Development) with assistance from ACIAR (Australian Centre for International Agricultural Research). Two of the three target areas in this program are 'Lifting Agricultural Productivity' and 'Improved Rural Livelihoods'.

There is also renewed institutional interest in overseas research for development, including by CSIRO, although given the constraints on public-sector funding, there is a need for investment models to be modernised. Co-investment models are not always the optimal way of funding overseas work if that work is predominantly knowledge diffusion rather than core research. Modern science investment may be better funded on a program basis encompassing a number of projects, in which the co-investment ratio employed is commensurate with how much of the work is consultancy versus research.

Emergence of new and renewed institutional arrangements in developing countries results in overseas development work being mutually beneficial — this is essential as modern biotechnology and simulation science come to dominate R&D in developed countries. Historically, developing countries would send their best students to developed countries for study. Many would not return. The building of in-country institutional capacity (see below) has the potential to train high-calibre students where they are most needed.

Finally, sophisticated multi-lateral partnerships are also supporting multi-institutional arrangements. These are described elsewhere in these proceedings by a range of authors.

Private–public partnerships in overseas agricultural R&D

How then can we tie these two issues together — the maturing of the Australian agricultural R&D sector with renewed Australian interest in international development work?

Australia's capacity to offer support to least-developed countries will be enhanced greatly if our public institutions work overseas in partnership with the private sector. While it is appropriate for the public sector to focus on providing aid in areas of immediate need for food and nutrition, public–private partnerships will work best if they are directed at developing enduring solutions to food security. Indeed, while some may assume that modern agricultural sciences may not have a lot to offer to these poorer farmers, public–private partnerships can actually assist poor farmers leap-frog agricultural advances, in the same way that developing countries have leapt over land-lines in telecommunications and moved straight to mobile phones.

Consider a couple of examples:

1. Not-for-profit private sector

Application of gene technology in poor countries is challenging. However, some organisations are rising to meet these challenges. Thus, the African Agriculture Technology Foundation (AATF) is a 'not-for-profit' organisation based in Nairobi. It acts as a broker for smallholder farmers in sub-Saharan Africa to deliver technology to them in public–private partnerships. AATF is funded by a variety of private-sector donor organisations and partners with both the private and public sector. For example, in West Africa, it is working towards insect-resistant cowpeas using gene technology. It is also assisting the relevant countries develop the appropriate infrastructure for regulation and marketing. The totality of the project is seen in Table 1.

Table 1. The West Africa Cowpea project (see http://www.aatf-africa.org/)

AATF's[A] roles
• Negotiating intellectual property access to insect resistance gene • Negotiating access to improved seed • Licensing of seed and technologies for distribution • Taking the licensor/licensee responsibilities • Ensuring seed production and availability • Providing technology liability protection • Ensuring social acceptability of improved cowpea varieties • Developing markets
Partners involved in the project
• Network for genetic improvement of cowpea for Africa • International Institute of Tropical Agriculture • Monsanto Company • The Kirkhouse Trust • National agricultural research systems in West Africa • CSIRO • US Aid • Rockerfeller Foundation

[A]African Agriculture Technology Foundation

AATF procures its expertise globally. Monsanto is providing the transgenes, Australian researchers at CSIRO are carrying out the gene transformation of cowpea, and others are assisting in the necessary field trials.

2. International R&D agencies

Centres of excellence are being established in Africa. The first of these is BECA (Biosciences Eastern and Central Africa), also based in Nairobi (http://www.africabiosciences.org). It was established by an initial investment of more than CAD30 million from the Canadian Government and has ongoing support from international development money and not-for-profit donor organisations. BECA aims to develop and apply bioscience research expertise to produce technologies that help poor farmers secure their farms and livelihoods.

Its management is under the stewardship of ILRI (International Livestock Research Institute). Australia is currently exploring means of providing support to this centre in a variety of ways. Our own institution is also looking at developing deep R&D connections with BECA — not in the old-fashioned somewhat lopsided way in which the developing country sent its students to Australia to do their training, but in a much more symmetrical relationship where Australian researchers spend time in Nairobi with BECA to do joint work in top facilities.

These examples demonstrate two roles for the private sector: not only as a financial donor to enable work to be done but also as providers of technology in ways that will benefit farmers.

Barriers to further involvement

Deeper engagement by the private sector in the least-developed countries requires some barriers to be overcome. One is the vexed issue of intellectual property (IP) protection and its transparency, a challenge because many developing countries do not have a patent system that supports innovation well. It is virtually impossible to know the true scope of patent protection in the developing world, making the positive side of the patent system (teachings through disclosure) inaccessible to the public. This makes investment decisions by both public and private sectors risky, and can make licensing problematic.

There are many possible solutions to this issue. Australian researchers are playing a key role internationally in developing frameworks that will assist the least-developed countries. Professor Richard Jefferson from Cambia (based at Queensland University of Technology) is a strong advocate of patent transparency and opportunities for more open-source licensing of key IP in biotechnology (Jefferson 2006). With the assistance of a variety of sponsors, including the Bill and Melinda Gates Foundation, he has championed the establishment of the 'Initiative for Open Innovation' (Cambia 2009). This new global facility is dedicated to making the world's innovation systems more transparent, inclusive and navigable. For the past ten years, Australia has hosted Cambia's patent lens (www.patentlens.net), the most popular non-profit global patent search facility. These facilities are of value to both developed and developing countries.

In a second initiative, Young Global Leaders from the World Economic Forum are promoting a Global Responsibility License (J. Moody, pers. comm., 2009). They are attempting to create a standard license for IP for development purposes. The focus of the project is to unlock IP to benefit the one billion poorest people in the world. This project has already received interest from a number of large patent-holders.

Public-sector institutions in Australia will need to ensure that contractual relationships with global life science companies not only protect the interests of Australian farmers to access IP partly paid for by Australian taxpayers, but also ensure that these arrangements do not exclude access for the least-developed countries.

It is important that we solve this issue around IP and biotechnology. Modern bioscience is relevant to poor farmers. It can greatly speed up breeding, even if the final product is not genetically modified. United international efforts are required for emerging global issues such as control of the wheat rust UG99. International consortia are working together using state-of-the-art science to provide germplasm that is resistant to this pathogen (BGRI 2009).

The way ahead for Australia

While Australia has reduced its public-sector funding in some of its more traditional areas of productivity research, investment remains strong in the areas of greatest challenge, not only for Australia but also for the globe. We are starting to see re-investment in productivity research on the back of private–public partnerships with global life science companies. This breeding activity is being more directed using knowledge available from genome maps.

There are challenges to increasing our overseas presence. There still are mixed views about the merits and importance of international work in public-sector R&D providers in Australia. An internet search of the web sites of major R&D providers shows they are often coy about their international work. Moreover, local industry is also vocal at times about potential competition if Australian researchers assist other countries improve their agricultural production.

We must find our voice in Australia for international development work and also develop better investment models for Australian researchers as the current project-based co-investment approach is under strain. A diminishing workforce and student base also provide challenges to increased activity. These gaps can be filled through international partnerships.

Finally, we suggest that public-sector investment should be directed towards a sustainable future. In such a model, public R&D funds would start with a strong focus on basic productivity issues but over time should aim to draw in private-sector investment in areas in which there is no longer market failure. In this way public funds can be gradually redirected to emerging problems.

We are convinced that Australian R&D has a significant role to play in contributing to solving food security issues in least-developed countries. Success will depend on the public sector being able to partner with the private sector in all its guises: from not-for-profit donor organisations to global life science companies.

Acknowledgements

The Australian Farm Institute gave permission to reproduce Figure 1. Gail Reekie assisted with the background material.

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Questions from the Audience

At the beginning of the conference members of the audience were invited to submit written questions throughout the day. These questions provided the basis for the Q&A session reported separately (page 84). It was not possible to deal in that session with all the issues raised, and some questions were merged in order to encompass as many as possible.

All questions submitted are reproduced below, together with the name of the writer and the speaker to whom they were addressed if this information was provided.

Authors of the following questions are unknown

To speaker: Not nominated

Q. Minister Smith highlighted the importance of agricultural development in the developing world; particularly in the Asia–Pacific region. AusAID currently funds only a few agricultural projects in this region. What will Australia's role be in developing agriculture in our neighbouring countries in the coming years? Will this be a major focus and, if so, will most assistance be bilateral or multilateral?

Q. The session on farm machinery by Dr Tullberg gave a strong message on how profit-taking can delay or prevent change for the good. This is a deep social and political issue of our time. Where is the space for more open dialogue between non-government organisations and the main organisations (the Crawford Fund, ACIAR, international corporations, etc.) represented here today? What about forming a three-way partnership to run some 'learning events' next year?

To speaker: Dr Ngongi

I note the reported success of the scheme in Rwanda entailing the bulk purchase of fertiliser by the government. How do you duplicate that on a much larger scale?

To speaker: Dr Roy

Q. Is there a danger that as other sources of phosphate and other fertilisers run out, developed countries will turn to African sources and drive up prices, depriving local African farmers of their fertilisers?

Q. By how much did the price of fertiliser bought by the Rwandan government exceed the price paid by the winning bidders from the private sector at the government auction?

Questioner: Professor Tim Reeves

To speaker: Dr Roy

Q. Do multinational fertiliser companies have any incentive to develop technologies that improve the efficiency of nutrient uptake? Such technologies — sorely needed — may reduce the companies' sales.

Questioner: Professor Roger Leigh

To speaker: Dr Roy

Q. What are the new technologies for fertiliser beyond the deep placement of urea? For example, Rothamsted Experimental Station is exploring the use of nanotechnology.

Questioner: Dr Helen Scott Orr

To speaker: Dr Roy

Will the IFDC Virtual Research Centre [The IFDC-managed 'Virtual Center of Excellence for Fertilizer Research and Development'] be examining interactions between microbial activity and fertilisers, as well as the possibilities of biochar?

To speaker: Dr Tullberg

Do we need new ways of engaging the engineering fraternity in the development of farm machinery appropriate for smallholder use and its local manufacture?

Questioner: Dr Anthony Whitbread

To speaker: Dr Ferroni

Q. In much of Sub-Saharan Africa, smallholder farmers are using a very low level of technology. Can you suggest catalytic public–private partnerships (PPPs) that can help to provide the initial boost needed to move the masses to where technology can be improved, perhaps through other PPPs?

Questioner: Dr Keith Hammond

To speakers: Various

Q. Please discuss the contention that, for public–private partnerships to be effective **rapidly** across large numbers of **small** farmers, **public monetary incentives direct to the farmers** to make the investment will be essential in the early years.

Questioner: Ms Caitlin Howlett

To speaker: Dr Gray

Q. In relation to the Small Scale Agroenterprise Development in the Uplands (SADU) project in Laos, how well are the animal health service providers accepted in the communities? Even though they are trained local people, how do you mitigate the fears of neighbouring farmers who are concerned that their livestock will become infected if they fail to vaccinate?

To speaker: Dr Roy

Q. The Urea Deep Placement project in Bangladesh has been great for yields and the environment. You mention that this has meant an increase in labour, which IFDC (an International Center for Soil Fertility) is working to reduce. Why reduce the labour intensiveness of this method when it could be positive for the local economy and labour workforce? [Why reduce labour intensity in an environment with excess labour?]

Questioner: Mr Walter Jehne

To speaker: Dr Lumpkin / Ms Armstrong

Q. As 67% of yield loss in maize is due to drought, what focus has there been on correcting this via root and or soil modifications and management rather than just breeding?

Questioner: Professor Helen Garnett

To speaker: Dr Ferroni

Q. Taking account of international commitments to enhance the productivity of subsistence farmers and the growing interest in the success of public–private partnerships (PPPs), where do you believe multilateral organisations such as the UN bodies (FAO etc.) can have greatest impact, and could they or should they be involved in the PPPs that are evolving?

To speaker: Dr Niebur

Q. What does the private sector see as the strengths of the multinational system that would add value to partnerships to help agriculture development and deployment to achieve impact for the poor?

Q. Crops from seed appear to be the major focus of the public–private partnerships (PPPs) with a focus on improving productivity of African agriculture: there is an opportunity to develop local seed merchants. What is being done or might be the opportunity for PPPs for vegetatively propagated crops — for example cassava and plantains — that are important for parts of Africa?

Questioner: Mr Mike Wight

To speakers: Drs Ferroni and Niebur

Q. Many examples have been given of public–private partnerships (PPPs) and their importance. However, there has been little discussion on how to reconcile the profit motive and intellectual property issues between the public sector that wants to produce public goods and the private sector that seeks profits and productive assets. Are the PPPs a significant proportion of business that actually can be scaled up widely? Or are they window-dressing/philanthropy/public relations exercises for private crop science and biotech firms?

To speakers: Dr Niebur and others

Q. The main goal of private companies is return on investment — sell a product, preferably on an ongoing basis. How do we promote R&D or knowledge dissemination with the prime goal of fostering regenerative farming practices, building soil carbon and biodiversity, and improving resilience to disease and drought?

Q. Do we need to build a partnership with a chemical company to develop environmentally, socially and economically regenerative farming systems? How did some civilisations survive for thousands of years?

Questioner: Dr Ted Wolfe

To speaker: Dr Niebur

Q. In public–private partnerships, how do you resolve conflicts between transparency (knowledge sharing) and secrecy on intellectual property issues?

Questioner: Mr Tony Fischer

To speaker: Dr Niebur

Q. Partnerships between the public sector and trans-national companies for research can have constraints on (1) germplasm made available for the research and or (2) publication of results (public domain versus restricted intellectual property). Why does this happen when GM events themselves are protected? Doesn't it hurt even the trans-national companies by restricting prospects of learning more about the germplasm's potential and limitations?

To speaker: Dr Gowda

Q. To develop good inbred parents for hybrid varieties, you need to know how the inbreeds perform in crossing. My understanding is that this knowledge is largely with the private companies and is not shared. How do you get around this constraint?

To speakers: Dr Lumpkin and Ms Armstrong

Q. Does the Water-Efficient Maize for Africa (WEMA) project have any restrictions on timely publication of research results relating to the performance of the GM event behind 'YieldGard'?

Questioner: Ms Georgina Hickey

To speaker: Ms Armstrong

Q. Janice herself asked the question 'Why is Monsanto involved with WEMA?' She said 'Because it is the right thing to do.' But we all know the underlying goal of all private companies is to make a profit — and understandable so. How exactly will Monsanto make a profit from its involvement in the WEMA project? What is it 'selling', and to whom?

Questioner: Mr David Shearer

To speaker: Dr Pardey and others

Q. Why are we discussing only public–private partnerships (PPPs) in relation to input suppliers, if only 19% of total food spending is captured by these input users (the farmers)?

Questioner: Mr Martin Royds

To speakers: Drs Ferroni and Pardey

Q. I'm a farmer who has gone through the mechanical (ploughing) era and then the chemical experiment before realising I was degrading my land by accelerating erosion and damaging soil structure and biology and depleting soil carbon. I am re-learning biological farming techniques. How can we encourage these regenerative practices and environmental improvement? Do we need partnerships with chemical companies to develop sustainable farming systems? Some agricultural systems survived for thousands of years without such involvement.

Questioner: Dr Kep Coughlon

To speakers: Drs Pardey and Tullberg

Q. If the private sector cannot capture benefits of research, how do we ensure involvement? Can we increase the appropriation of benefits?

Questioner: Dr Albert Rovira

To speakers: All

Q. The use of genetically-modified (GM) plants for food is not accepted by the general population. How can we change this?

Q. While the world is so short of food, how can we justify growing food crops for biofuel?

Questioner: Ms Jenny Goldie

To speaker: Dr Ferroni

Q. In places in Africa the population exceeds the agricultural productivity potential (according to Professor R. Lal). What can be done once maximum agricultural productivity is achieved?

To speaker: Mr Stephen Smith

Q. While we may commend you on your recent four-year commitment to the World Food Program, what is to be done in countries such as Ethiopia where population growth is so large it offsets gains in agricultural productivity?

Questioner: Dr Jon Tanner

To speaker: Crawford Fund

Q. Congratulations Crawford Fund. Another excellent conference. How can we extend Crawford Fund – like activities to New Zealand?

APPENDIX 2

Delegate List
The Crawford Fund International Conference 2009

(EXCLUDING THOSE NOMINATING PRIVACY)

Last name	First name, Title	Organisation
Ahammad	Helal, Dr	Australian Bureau of Agricultural and Resource Economics
Allen	John, Dr	AAHL
Anandajayasekeram	Cynthia, Ms	The National Farmers Federation
Andrew	Carolyn, Mrs	
Andrew AO FTSE	Neil, The Hon. .	The Crawford Fund Board of Governors
Andrews	Peter, Professor	Chief Scientist, Queensland Government
Angus	John, Dr	CSIRO
Angus	Leecia, Mrs	Grains Research and Development Corporation (GRDC)
Appiah-Kubi	Benjamin, Mr	International Voluntary Organisation for Women, Education and Development
Arkle	Peter, Mr	Syngenta Foundation for Sustainable Agriculture
Armstrong	Janice, Ms	Monsanto Australia Ltd
Ashton	Darral, Mr	Plant Health Australia
Atkinson AO	Sallyanne, Ms	The Crawford Fund Board of Governors
Aubert	Andrew, Mr	Syngenta Foundation for Sustainable Agriculture
Austin	Nick, Dr	ACIAR
Baldwin	Madeleine, Ms	Department of Agriculture, Fisheries and Forestry
Barlow	Snow, Professor	University of Melbourne
Barlow	Chris, Dr	ACIAR
Bartlett	Fiona, Ms	Department of Agriculture, Fisheries and Forestry
Bates	Andy, Mr	Bates Agricultural Consulting
Baxter	Les, Mr	Australian Centre for International Agriculture Research (ACIAR)
Baxter	Peter, Mr	Acting Director-General, AusAID
Becker	Joy, Dr	University of Sydney Faculty of Veterinary Science
Birmingham	Simon, The Hon. Senator	
Birrell	Nicole, Ms	Grains Research and Development Corporation (GRDC)
Blackwell	John, Professor	Charles Sturt University
Blight	Sharon, Mrs	
Blight AO FRSA	Denis, Dr	Executive Director, The Crawford Fund
Boakye	Akwasi, Mr	Boakye Scala Ent.
Bourke	Gerald, Senior Donor Rel	UN World Food Programme
Bowman	Alison, Dr	Industry & Investment NSW — Primary Industries
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Branford-Bowd	Rebecca, Ms	Consultant
Brassington	Juliette, Ms	AusAID
Brown AM FTSE	Alan, Mr	The Crawford Fund
Bruce	Sarah, Dr	Bureau of Rural Sciences
Bryant	Rebecca, Ms	AusAID
Buckle	Ken, Emeritus Professor	University of NSW
Burke MP	Tony, The Hon. Minister	Minister for Agriculture, Fisheries and Forestry
Bush	Russell, Dr	University of Sydney

Last name	First name, Title	Organisation
Cameron	Doug, The Hon. Senator	
Campbell	Lindsay, Dr	University of Sydney
Carberry	Peter, Dr	CSIRO
Carmichael	Andrew, Mr	Mike Stephens & Associates
Carter	Julie,	CSIRO
Chemin	Yann, Dr	IC Water
Chesson	Jean, Dr	Bureau of Rural Sciences
Chilver	Alwyn, Mr	AusAID
Cho	Jae Hyuk	Korea Institute of S&T Evaluation and Planning
Coffey	Shaun, Professor	Industrial Research Ltd
Copeland	Les, Professor	University of Sydney
Cornish	Peter, Professor	University of Western Sydney
Costello AO	Tim, Rev.	World Vision
Coughlan	Kep, Dr	The Crawford Fund Queensland Coordinator
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Craig	Theresa, Dr	Agribusiness Association of Australia
Craswell	Eric, Dr	The Crawford Fund
Craswell	Alison, Mrs	
Crompton	Heather, Mrs	Southern Cross University
Cummins	Jay, Dr	Rural Solutions SA
Daly	Joanne, Dr	Agribusiness, CSIRO
Davis	Jan, Ms	Plant Health Australia
Dixon	John, Dr	ACIAR
D'Occhio	Michael, Professor	The University of Queensland
Dooley	Corinne, Ms	The National Farmers' Federation
Dreyfus MP	Mark, Mr	Federal Member for Isaacs
Duncan	Ron, Professor	The Australian National University
Enright	Terry, Dr	The Crawford Fund Board of Governors
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Ferroni	Marco, Dr	Syngenta Foundation for Sustainable Agriculture
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Fischer	Tony, Mr	The Crawford Fund ACT Coordinator
Fisher	Tom, Mr	Australian Academy of Technological Sciences and Engineering
Fitt	Gary, Dr	CSIRO
Forshaw	Michael, The Hon. Senator	
Fox	Paul, Dr	ACIAR
French	Bruce, Mr	Learn Grow
French	Peter, Deputy Regional	UN World Food Programme
Furner	Mark, The Hon. Senator	
Gale	Dave, Mr	Charles Sturt University
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Glick	Harvey, Dr	Monsanto

Last name	First name, Title	Organisation
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Graser	Hans-Ulrich, Dr	University of New England
Gray	Doug, Dr	ACIAR
Gray	John, Dr	Bureau of Rural Sciences
Gready	Jill, Professor	Australian National University
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Hammond	Keith, Dr	Consultant
Hanjra	Munir, Mr	IC Water
Hann	Michael, Mr	Sustainable Food Lab
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Hartley	Margaret, Ms	ATSE
Harvey	John, Mr	Grains Reserch and Development Corporation (GRDC)
Hayes FAIAST	Ted, Mr	The Crawford Fund Victoria Coordinator
Hearn	Simon, Mr	ACIAR
Hefner	Clif, Mr	
Hegarty	Vanessa, Ms	Advisor to Senator McMullan
Hickey	Georgina, Ms	ACIAR
Higgins	Tj, Dr	CSIRO
Horne	Peter, Dr	ACIAR
Howlett	Caitlin, Ms	Student
Hull MP	Kay, Mrs	Member for Riverina
Hurley	Annette, The Hon. Senator	
Hyne	Nin, Ms	Department of Agriculture, Fisheries and Forestry
Ingram	Mark, Dr	Business for Millennium Development (B4MD)
Ingram	Jim, Mr	
Jackson	Tamara,	International Centre of Water for Food Security
Jackson	Norton, Dr	Energy Exploration
Jackson	Phillip, Mr	The Crawford Fund
Jehne	Walter, Mr	Healthy Soils Australia Ltd
Jones	Cynthia, Ms.	World Food Programme
Keating	Brian, Dr	CSIRO
Keatinge	Dyno, Dr	AVRDC — The World Vegetable Centre

Last name	First name, Title	Organisation
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Kerin AM FTSE	John, The Hon.	The Crawford Fund Board of Governors
Kershaw	Ian, Mr	AusAID
Kilian	Andrzej,	Diversity Arrays Technology Pty Ltd
Laffan	Judith, (Ms)	Department of Foreign Affairs and Trade
Lagudah	Evans, Dr	CSIRO
Lansley	David, Dr	World Vision Australia
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Lawrenson	John, Mr	RIRDC
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Leigh	Roger, Professor	University of Adelaide
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Longson	Ian, Mr	Kondinin Group
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Martin	Xavier, Mr	Plant Health Australia
McAllister	Norm, Mr	RIRDC
McCluskey	Su, Ms	Council of Rural Research and Development Corporations Chairs
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McComb	Jen, Emeritus Professor	The Crawford Fund West Australia, Coordinator
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McKenzie	John,	Live and Learn (NGO)
McMullan MP	Bob, The Hon.	Parliamentary Secretary for International Development Assistance
McNeil	David, Professor	University of Tasmania
Midgley	Stephen, Mr	Salwood Asia Pacific Pty Ltd
Millar	Joanne, Dr	Charles Sturt University
Mitchell	Ian, Mr	Rural Solutions SA
Morthorpe	Kevin, Mr	Pioneer Hi-Bred Australia Pty Ltd
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Ngongi	Namanga, Dr	Alliance for a Green Revolution in Africa
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Nietschke	Brett, Mr	AusAID
Ninnes	Peter, Dr	ICRISAT
O'Brien	Peter, Dr	RIRDC
O'Connell	Conall, Mr	Department of Agriculture, Fisheries and Forestry

Last name	First name, Title	Organisation
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Peishi	Zalynn, Ms	CARE Australia
Perrett	Keith, Mr	Grains Research and Development Corporation (GRDC)
Perrett MP	Graham, Mr	Member for Moreton
Persley	Gabrielle, Dr	ILRI
Pingali	Prabhu, Dr	Bill and Melinda Gates Foundation
Polak Scowcroft	Caroline, Ms	Agriculture Australia Consultants
Pratley	Jim, Professor	Charles Sturt University
Purvis	Ian, Dr	CSIRO
Quinn	Dan, Mr	CropLife Australia
Radcliffe AM FTSE	John, Dr	The Crawford Fund Board of Governors
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Ramsay	Gavin, Dr	University of Western Sydney
Reade	Catherine, Ms	The Crawford Fund
Reading	Peter, Dr	Grains Research and Development Corporation (GRDC)
Rees	Gwendolen,	Australian Bureau of Agricultural and Resource Economics
Reeves	Tim, Professor	Grains Research and Development Corporation (GRDC)
Rhodes	Nathan, Mr	Department of Agriculture, Fisheries and Forestry
Robertson	Graeme, Professor	Grains Research and Development Corporation (GRDC)
Roth	Christian, Dr	CSIRO Sustainable Ecosystems
Rovira AO FTSE	Albert, Dr	The Crawford Fund South Australia, Coordinator
Roy	Anita, Dr	
Roy	Amit, Dr	IFDC
Royds	Martin, Mr	Natural Sequence Association
Ryan	Jim, Dr	Consultant
Sale	Peter, Dr	La Trobe University
Samundsett	Colin,	Private capacity
Sayers	Keith, Mr	ALP — International Affairs Policy Committee
Scott-Orr	Helen, Dr	The Crawford Fund NSW Committee
Scullion	Nigel, The Hon.	Deputy Leader of the Nationals, Shadow Minister for Human Services
Seaby	Nikki, Ms	Assistant to the Minister
Sedimo	Omphile, Ms.	Botswana High Commission
Sheales	Terry, Dr	ABARE
Shearer	David, Mr	ACIAR
Sheeran	Josette, Ms	UN World Food Program
Simmons	Luke, Mr	AusAID
Sinn	Michelle, Mrs	Queensland Primary Industries and Fisheries (DEEDI)
Slack-Smith	Richard (Dick), Mr	The Crawford Fund NT Coordinator

Last name	First name, Title	Organisation
Slipper MP	Peter, The Hon.	Federal Member for Fisher
Smith	Sally, Professor	AVRDC — The World Vegetable Centre
Smith	Frank Andrew, Professor	University of Adelaide
Smith	Ed, Mr	AusAID
Smith MP	Stephen, The Hon.	Australian Minister for Foreign Affairs
Snell	Selwyn, Mr	Plant Health Australia
Spurrett	Sam, Mr	Coffey International Development
Standen	Bruce, Dr	The Crawford Fund NSW Coordinator
Stapley	Ben, Mr	CropLife Australia Limited
Stauffacher	Mirko, Dr	Australian Centre for International Agricultural Research (ACIAR)
Stelling	Anne, Ms	Charles Sturt University
Stephens	Ursula, The Hon. Senator	
Sutton	Robert, Mr	Austrade
Swift	Roger, Professor	The University of Queensland
Tanner	Jon, Dr	OANZ
Tarus	Stephen K., His Excellency	Kenya High Commission
Taylor	Michael, Mr	Murray Darling Basin Authority
Templeton	Debbie, Dr	ACIAR
Thompson	Neil,	ABARE
Toyota	Terri, Director	UN World Food Programme
Trethowan	Richard, Dr	Sydney University
Troeth	Judith, The Hon. Senator	
Trood	Russell, Senator	Senator for Queensland
Tullberg	Jeff, Dr	CTF Solutions
Ullah	Muhammad Kaleem, Mr	International Centre of Water for Food Security
Uotila	Auli, Ms	Department of Agriculture, Fisheries and Forestry
Van Oostende	Marchien, Ms	The Crawford Fund
Wade	Len, Professor	Charles Sturt University
Watkins	Philip, Mr	CSIRO
Webb	Kate, Ms	Cardno Acil
Whitbread	AntHon. y, Dr	CSIRO Sustainable Ecosystems
Whittington	Richard, Professor	University of Sydney
Wight	Mike, Mr	Department of Foreign Affairs and Trade
Wild	Simon, Mr	Cundall
Williamson	Greg, Mr	Department of Agriculture, Fisheries and Forestry
Windsor MP	Tony, Mr	Member for New England
Wolfe	Edwin (Ted), Dr	Charles Sturt University
Wortley	Dana, The Hon. Senator	Labor Senator for South Australia
Wright	Lisa, Ms	ACIAR Governance and Communications
Zappia MP	Tony, Mr	Federal Member for Makin
Zoltan	Lukacs,	Grains Research and Development Corporation (GRDC)
Zsogon	Austin, Mr	RSBS The Australian National University

Media Coverage

AS AT 1 NOVEMBER

Media in attendance/interviews held

AAP	Keatinge – article filed nationally 27.10
AP	Ferroni, Pardey, Pingali – article filed internationally 27.10
Australian TV Network	Gowda, Pingali, Pardey, Ferroni, Keatinge – international TV news item filed
Rural Press	Keatinge, Gray – for publications 5.11 and online
Good Fruit and Vegetables	Keatinge – for November edition
Weekly Times	Keatinge, Niebur – stories filed 28.10
Dow Jones	Niebur – article filed internationally
Radio National Bush Telegraph	Ferroni – broadcast live nationally and throughout Asia Pacific
Radio National Breakfast	Ngongi – broadcast live nationally and throughout Asia Pacific
Radio Australia for Asia Pacific and Pacific Beat	Gowda, Pingali, Pardey, Ferroni, Keatinge – broadcast live nationally and throughout Asia Pacific
Radio Australia Today	Ngongi – broadcast live nationally and throughout Asia Pacific
ABC Canberra	Blight
ABC Rural	Ferroni, Pardey, Pingali, Ngongi, Gray, Roy – stories picked up in each state and special webfeature online
National Commercial Rural news	Blight – national syndicated rural news service
National Community Radio Current Affairs	Blight, Ngongi, Pingali – story filed for 50 stations nationwide

Listing of coverage

24.10

Blight	*Sir John Crawford and Australia's international agricultural research* Radio National Late Night Live

26.10

Ngongi	*Food shortages and how to fix them* Radio Australia Today program Radio Australia Today program
Blight/Ngongi/Pingali	*Has food security been lost in the maize?* National Community Radio, Current Affairs The Wire 50 stations
Blight	National Commercial Rural (broadcast nationally on commercial networks 3LO, 6PR, 4BC, 5AA etc
Blight	*Crawford Fund wants private sector involvement in agricultural R&D* ABC National Rural News
Lumpkin	ABC Victoria Statewide Drive at 5.10pm
Denis Blight	*Can private sector research feed the world?* ABC Rural Canberra Region

27.10

Ngongi	*Food crisis in Africa* Radio National Bush Telegraph
Ferroni, Pingali,	

Ngongi, Keatinge	*Science, agriculture debate global food needs* Radio Australia Asia Pacific Program
Keatinge, Ngongi, Ferroni	*Private–public partnerships may deliver food security* Radio Australia News
Gowda, Ngongi Keatinge Pingali	*Alleviating hunger* Australia TV Network (Australia's international TV news service): http://australianetworknews.com/story.htm?id=23596 http://australianetworknews.com/story.htm?id=23598 http://australianetworknews.com/story.htm?id=23661
Niebur	PR Web http://www.prweb.com/releases/2009/10/prweb3117634.htm
Ferroni	Canadian Press http://www.google.com/hostednews/canadianpress/article/ALeqM5gvK0ZUN5028lNYlrDwjLXF3YazPA
Blight	ABC 774 Melbourne Mornings 7.20am
Overview	ABC Canberra Morning Sarina Locke
Ngongi	ABC Canberra Alex Sloan
Niebur/Ferroni	Dow Jones Newswire (clipping)
Pingali	ABC Statewide Drive SA 5.50pm
Gowda	SBS Radio Hindi 3pm (link being provided)
Roy	ABC 666 Drive Program (Clipping)
Conference mention	Radio Australia international e-newsletter

28.10

Keatinge	Weekly Times p.3 (Clipping)
Conference mention	*We need another Green Revolution* Science Media http://www.croplifeaustralia.org.au/default.asp?V_DOC_ID=2249
Pardey	National Rural Bulletin online e-newsletter (Clipping)
Keatinge	Business Spectator http://www.businessspectator.com.au/bs.nsf/Article/Overhaul-urged-for-vegetable-industry-X8VXD?OpenDocument
Croplife	Opinion piece (Clipping)
Ferroni	Radio National Bush Telegraph http://www.abc.net.au/rural/telegraph/content/2009/s2726386.htm
Keatinge	Radio Australia Pacific Beat http://www.radioaustralia.net.au/pacbeat/stories/200910/s2726090.htm
Pardey	*Professor says agricultural research has huge pay-off* ABC National Rural News http://www.abc.net.au/rural/news/content/200910/s2726168.htm
Roy	ABC Canberra Early Breakfast 5.52 (Clipping)
Roy	ABC Canberra Early Breakfast 06:21 AM Ross Solly (Clipping)
Feature	ABC Rural http://www.abc.net.au/rural/content/2009/s2726201.htm
Monsanto	ABC National Rural News http://www.abc.net.au/rural/news/content/200910/s2726294.htm
Monsanto	Radio National Rural News http://www.abc.net.au/rural/telegraph/content/2009/s2724082.htm
Overview	ABC Canberra Rural Report http://www.abc.net.au/rural/news/content/200910/s2724392.htm
Roy	*Feed the world* ABC Canberra http://www.abc.net.au/rural/content/2009/s2726201.htm
Pardey/Ferroni	*Feed the world with private–public partnerships* ABC Canberra http://www.abc.net.au/rural/content/2009/s2726201.htm
Ngongi	*African Green Revolution* ABC Canberra http://www.abc.net.au/rural/act/canberra/
Roy	*Fertiliser efficiency to feed the world* ABC Canberra Rural http://www.abc.net.au/rural/regions/content/2007/s2726021.htm

Pardey/Ferroni	*Public–private partnerships in agricultural research* ABC Canberra Rural http://www.abc.net.au/rural/regions/content/2007/s2726021.htm
Ngongi	*African agricultural development* ABC Canberra Rural http://www.abc.net.au/rural/regions/content/2007/s2726021.htm
Pardey/Ferroni	ABC NSW Country Hour http://www.abc.net.au/rural/nsw/content/2009/10/s2726671.htm
Pardey/Ferroni	ABC Victorian Country Hour http://www.abc.net.au/rural/vic/content/2009/10/s2726520.htm
Pardey/Ferroni	ABC Tasmanian Country Hour http://www.abc.net.au/rural/tas/content/2009/10/s2726621.htm
Roy	ABC WA Rural Report (Clipping)
Roy	ABC North Coast NSW http://www.abc.net.au/rural/regions/content/2007/s2725937.htm
Ferroni/Pardey	ABC WA Country Hour Broome (Clipping)

29.10

Niebur	Weekly Times http://www.weeklytimesnow.com.au/article/2009/10/29/128205_horticulture.html
Conference mention	ABC 666 Canberra (Canberra) Morning 11:11 AM Alex Sloan (Clipping)
Lumpkin/Armstrong	*CIMMYT and Monsanto collaborating* ABC Rural Canberra http://www.abc.net.au/rural/regions/content/2007/s2727056.htm
Lumpkin/Armstrong	*GM drought tolerance still waiting* ABC Rural http://www.abc.net.au/rural/content/2009/s2727327.htm
Lumpkin/Armstrong	NSW Country Hour http://www.abc.net.au/rural/nsw/content/2009/10/s2727733.htm
Roy	ABC North and West SA (Port Pirie) Rural Report 6:40 AM (Clipping)
Roy	*Possible fertiliser solution* ABC Country Hour SA http://www.abc.net.au/rural/sa/northandwest/
Pardey	Queensland Country Hour 12:51 PM http://www.abc.net.au/rural/qld/content/2009/10/s2727788.htm

30.10

Keatinge	Weekly Times http://www.weeklytimesnow.com.au/article/2009/10/30/127751_business-news.html
Gray	NSW Country Hour http://www.abc.net.au/rural/nsw/content/2009/10/s2728938.htm
Gray	ACT Rural Report http://www.abc.net.au/rural/act/canberra/
Roy	*Cut fertiliser to increase food production* ABC Country Hour North Tasmania http://www.abc.net.au/rural/tas/northtas/

Future

Keatinge	Rural Press
Gray	Rural Press
Keatinge	Good Fruit & Vegetables
McMullan	National ABC TV Fora http://www.abc.net.au/tv/fora/about.htm
	Radio National Fora http://www.abc.net.au/rn/foraradio/about/
Sheeran	National ABC TV Fora http://www.abc.net.au/tv/fora/about.htm
	Radio National Fora http://www.abc.net.au/rn/foraradio/about/

Other Crawford Fund Publications since 2004

Brown, A.G. (ed.) 2004. *Fish, Aquaculture and Food Security: Sustaining Fish as a Food Supply*. Record of a conference conducted by the ATSE Crawford Fund, Parliament House, Canberra, 11 August 2004. The ATSE Crawford Fund, Parkville, Vic. iv + 85 pp. ISBN 1 875618 82 1

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.

Brown, A.G. (ed.) 2006. *Forests, Wood and Livelihoods: Finding a Future for All*. Record of a conference conducted by the ATSE Crawford Fund, Parliament House, Canberra, 16 August 2005. The ATSE Crawford Fund, Parkville, Vic. vi + 91 pp. ISBN 1 875618 86 4

Anon. 2006. *The ATSE Crawford Fund Report 1 July 2005–30 June 2006*. The Fund, Parkville, Vic. 28 pp. http://www.crawfordfund.org/publications/pdf/annualreport2006.pdf.

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

Brown, A.G. (ed.) 2008. *Biofuels, Energy and Agriculture: Powering Towards or Away from Food Security?* Record of a conference conducted by the ATSE Crawford Fund, Parliament House, Canberra, 15 August 2007. The ATSE Crawford Fund, Parkville, Vic. vi + 54 pp. ISBN 1 875618 95 3

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.

Anon. 2008. *The Crawford Fund: An Initiative of the Australian Academy of Technological Sciences and Engineering. Annual Report 1 July 2007 to 30 June 2008*. The Fund, Deakin, ACT, 36 pp. http://www.crawfordfund.org/publications/pdf/annualreport2008.pdf

Brown, A.G. (ed.) 2009. *Agriculture in a Changing Climate: The New International Research Frontier*. The ATSE Crawford Fund Fourteenth Annual Development Conference, Parliament House, Canberra, 3 September 2008. The ATSE Crawford Fund, Deakin, ACT. vi + 72 pp. ISBN 978-1-921388-01-9

Gupta, V.V.S.R., Ryder, M. and Radcliffe, J. (eds) 2010. *The Rovira Rhizosphere Symposium*. Celebrating 50 years of rhizosphere research. A festschrift in honour of Albert Rovira AO FTSE, Friday 15 August 2008. SARDI Plant Research Centre, Adelaide. The Crawford Fund, Deakin, ACT. (In press). ISBN 978 1 921388 07 1

The Crawford Fund newsletter, *Highlights*, is available from the Fund's website (http://www.crawfordfund.org/index.htm) or in printed form. In 2009, one issue was published.

The three 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

The Crawford Fund facilitated an award-winning one-hour TV documentary, *Seed Hunter* (1988) that follows Australian scientist Dr Ken Street on a quest through Central Asia to find rare genes that may save our food from the looming threat of climate change. More details are at http://www.seedhunter.com/.