THE CRAWFORD FUND

For a Food Secure World

THE SCRAMBLE FOR NATURAL RESOURCES

MORE FOOD, LESS LAND?

The Crawford Fund
2012 Annual Parliamentary Conference
Parliament House, Canberra
9–10 October 2012

Editor: Ann Milligan

THE CRAWFORD FUND

For a Food Secure World

THE SCRAMBLE FOR NATURAL RESOURCES

More food, less land?

The Crawford Fund

18th Annual Parliamentary Conference

Parliament House, Canberra ACT, Australia

9–10 October 2012

Editor: Ann Milligan

The Crawford Fund

The Australian Academy of Technological Sciences and Engineering established the Crawford Fund in June 1987. Named in honour of the late Sir John Crawford, the Fund commemorates his outstanding services to international agricultural research. The Crawford Fund is a non-profit, non-government organisation, dedicated to raising awareness of the benefits to developing countries and to Australia of 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.

The Fund promotes and supports international R&D activities in which Australian research organisations and companies are active participants. It supports the work of the Australian Centre for International Agricultural Research (ACIAR), the Australian Agency for International Development (AusAID), the CGIAR Consortium and other international research centres.

The annual Parliamentary conference is a key part of the Fund's public awareness campaign, which increases understanding of the importance and potential of international agricultural research, its achievements and needs.

The Fund also runs training programs that fill a niche by offering practical, highly focused non-degree instruction to women and men engaged in agricultural research and management in developing countries.

The Crawford Fund
Level 3, 10 National Circuit
Barton ACT 2600, Australia

Phone: +61 (0)2 6188 4370

Email: crawford@crawfordfund.org

Web: http://www.crawfordfund.org/

ISBN 978 1 921388 23 1

Cite this work as:
The scramble for natural resources: More food, less land? (Ed. A. Milligan) Proceedings of the Crawford Fund 18th Annual Parliamentary Conference, 9–10 October 2012, Canberra, Australia.

Transcriptions	TranscriberOnline, www.transcriberonline.com
Cover	Stacey Phillis, Graphic Force
Photographs	By courtesy of the Crawford Fund, the conference speakers, CIFOR, CIAT and ACIAR
Editing, Production	**ENRiT**: Environment & Natural Resources in Text

Contents

Page no.

ii The Crawford Fund

iv Acknowledgements

v **Foreword**
The Hon. John Kerin AM

The Sir John Crawford Memorial Address

1 **Agriculture: The challenges of the 21st century**
Professor Sir John Beddington CMG FRS

Opening address

8 **Opening Address**
Senator the Hon. Bob Carr

Keynote addresses

10 **The scramble for natural resources: How can science help?**
Dr Frank Rijsberman

21 **Can we feed a growing world and sustain the planet?**
Professor Jonathan Foley

28 **A global land rush?**
Dr Derek Byerlee

Declining land availability for food production

39 **The slumbering giant: Land and water degradation**
Dr Andrew Noble

52 **Impacts of mining on land and water resources**
Professor Chris Moran

60 **Landscape urbanisation and food security**
Professor Xuemei Bai

69 **Forest lands: More than just trees**
Dr Christine Padoch

Sustainable agriculture to meet food security targets

77 **Closing the yield gap through integrated soil fertility management**
Dr Nteranya Sanginga

Future prospects: The case for Malthusian optimism

96 **Helping farmers innovate to harvest more from less**
Dr Trevor Nicholls

107 **Can we free the world of hunger and Malthus's shadow forever?**
Dr Shenggen Fan

Conference overviews

115 **Conference overview and summary**
Dr Denis Blight AO

128 **Q&A sessions**
Tuesday 9 October
Wednesday 10 October

154 Delegates and Agricultural Student Scholars 2012

160 Media coverage 2012

Acknowledgements

The Crawford Fund wishes to thank the Chairs and Moderators of the conference sessions, and the supporters and sponsors of the 2012 Annual Parliamentary Conference:

Hon. John Kerin AM, Chairman, The Crawford Fund

Ms Cathy McGowan AO, Agricultural Consultant and Trainer

Ms Margaret Hartley, CEO, Australian Academy of Technological Sciences and Engineering

Mr Peter Baxter, Director General, AusAID

Professor Shaun Coffey, CEO, Industrial Research Ltd, New Zealand

Dr Denis Blight AO, CEO, The Crawford Fund

AusAID (Australian Agency for International Development)

Austraining International

ACIAR (Australian Centre for International Agricultural Research)

Australian Agricultural Company Limited (AACo)

Australian Agricultural Resource Economics Society (AARES)

Australian Academy of Technological Sciences and Engineering (ATSE)

Australian International Food Security Centre

The University of Adelaide

ANU Photosynthesis Initiative

Australian Government Department of Agriculture, Fisheries and Forestry (DAFF)

CAB International

CGIAR Consortium

Centre for International Forestry Research (CIFOR)

Cooperative Research Centres (CRC) Association

CSIRO

Grains Research and Development Corporation

International Food Policy Research Institute (IFPRI)

International Institute of Tropical Agriculture (IITA)

Industrial Research Ltd

International Water Management Institute (IWMI)

Rural Industries Research and Development Corporation

School for Agriculture and Food Sciences, The University of Queensland

Sustainable Minerals Institute, The University of Queensland

Tasmanian Institute of Agriculture

World Vegetable Centre

Foreword

In the principled belief that a conference built around high quality speakers making evidence-based presentations will lead to more sensible discussion on policy options, the Crawford Fund has never shied away from controversial topics — and we have addressed quite a few in our 25 years.

On this basis, I am confident that with this 2012 conference we have been able to further the Australian debate about issues such as foreign investment in land, forestry and the best use of water. The conference also discussed the issues confronting mining and rural industries as they relate to both developing countries and Australia, and how agricultural research, development and policy change can help ensure that the range of competitors for the globe's natural resources all get the 'fair go' they and the planet deserve.

We were particularly fortunate to have an outstanding panel of international and Australian speakers, all of whom came here without remuneration, from as far away as West Africa, Europe and the USA. Their participation would not have been possible without our sponsors, including in many cases the speakers' host organisations. They are all listed in the Acknowledgements.

Interest in the 2012 conference was such that we needed to close registrations early. The point about the number of delegates is that, as a scan of the list reveals, they comprised a very broad grouping of people with an interest in food security: scientists and researchers, policy and decision makers, farmers, NGO representatives, aid workers and members of the general public. Many of these return again and again to this annual event, to address sometimes controversial but always interesting issues.

We are particularly pleased that we were able to again offer scholarships for young Australian scientists, and concessions for students, as part of our efforts to encourage young people into careers for agricultural R&D. A further widening of our demographic at the 2012 conference was achieved through attendance by a number of African scientists, who were beneficiaries of Australia Awards.

None of this would have been possible without the extraordinary talent and commitment of our very small secretariat led by Denis Blight. I express my appreciation for their hard work, and make particular mention of Cathy Reade, the Fund's inimitable Director of Public Affairs and Communication, and Director of the Conference.

Hon. John Kerin AM
Chairman, The Crawford Fund

SIR JOHN CRAWFORD MEMORIAL ADDRESS

Agriculture: The challenges of the 21st century

Professor Sir John Beddington CMG FRS
Government Chief Scientific Adviser, United Kingdom

Abstract

The Sir John Crawford Memorial Address has been presented since 1985, in honour of the distinguished Australian civil servant, educator and agriculturalist in whose name the Crawford Fund was established. Sir John Crawford was a remarkable Australian who contributed at the highest levels, and was a passionate supporter of international agricultural research for development.

This talk draws attention to four current and interrelated trends that suggest the world will be rather different by 2025, only 13 years away. The four trends are: population growth; rapidly expanding urbanisation especially in Africa and Asia; changes in patterns of demand for food and energy by the increasingly large and prosperous 'middle class'; and climate change. Beyond 2025, the prospects are frightening if the momentum of both population growth and greenhouse gas emissions (which, once in the atmosphere, continue to affect climate for 20 years) is not very soon brought under control. A range of solutions are available to improve agricultural production and therefore food security, but they need strong corresponding improvements in storage practices, pest and disease management, and new attitudes to wastage of food. Food supplies and food prices depend on the weather all over the world, and the extra billion people by 2025, living mostly in cities, will need food and energy. Effective action on the factors — including agricultural practices — that are driving climate change is now very urgently needed.

Let me begin by saying that much of the commentary on food and water security and climate change focuses, in my view, too far into the future. Experts talk about 2050. Yet many people will not be too concerned about 2050 because we will be over 100 years old by that time. While that is a personal view, I put it to you that the world must be thinking much more about the immediate trajectory.

It appears to be little recognised that several trends are happening and will continue irrespective of human intervention. The first one is population growth. The world has seven billion people now; by 2025, all projections say there will be a further billion on the planet. That is, in 13 years time, there will be another billion people, roughly divided between Africa and Asia.

That is one of the trends, and really, because of the structure of human demography, there is every chance of that growth continuing inexorably over the next 13 years.

The second trend that is happening in the world and is similarly inexorable is growth in urbanisation. In 2010, for the first time, the world's urban population exceeded the rural. The rural population of the world is expected to decline and the urban population to increase. To put that into context with the population growth that I spoke of, it implies for example that in Africa in the next 13 years there will be a further thousand cities of 500,000 people each. In Asia, about 500 new cities of about a million people each.

That is a completely breathtaking change over that timescale. Yet these are two fundamental trends and nothing is going to alter them.

Another trend, which is more problematic and may or may not happen, is that people are becoming more prosperous. There is still enormous poverty in the world, but by and large in many parts of the world there is an increase in what might be termed the 'middle classes', along with the purchasing power that is associated with that term.

The fourth trend that is really important — and one that I deal with continually in Britain and other parts of the world too — is climate change. Because of the delays that occur naturally in our climate system, the greenhouse gases and other constituents that are in the upper atmosphere at the moment will determine climate for at least another two decades or possibly a little more. Now I know that in all societies there is a degree of climate scepticism, and I confess to being extremely unsympathetic to it. Science grows by criticism; science grows by scepticism; and indeed the odd human being, the odd scientist in human history, has broken the consensus and disagreed and been shown to be right. Galileo was one such person; Copernicus was another; but these are rare.

In terms of thinking about whether in fact climate change is happening, whether in fact the scientific evidence is appropriate, I would like to quote Stephen Chu. Now Stephen Chu, Nobel Prize winner in physics, runs the Department of Energy for President Obama. The Department of Energy has a budget something akin to the budgets of medium-size European states: it is big, and Stephen Chu is a 'serious player'. He had a marvellous quote that I heard a couple of years back when he was dealing with the governors of the western states, whom you might imagine would not be entirely encouraging about a world of low-carbon economies. He said: 'People are entitled to their own opinions but not their own facts'.

It is statement that I heartily endorse. We have got to be evidence-based. The evidence, that climate change is happening, is everywhere.

It is very difficult to attribute individual events — weather-related events — to climate change. Although work can be done on them, it is always very difficult. Yet the weight of evidence that climate change is occurring is utterly compelling and by and large it convinces the vast majority of scientists that work in this area. One of the interesting comments that some people make is: 'Well scientists of course would be saying climate change is happening, because that way they will get more research grants to study climate change!' — and, to an extent, there may be some natural truth in that.

However, not just scientists but also most of the major corporations in the world believe climate change is happening and are preparing for it. Those who are probably the most cynical and careful people to think about it are insurance companies. Munich Re, the largest insurance company, or re-insurance company, in Europe has analysed natural catastrophes worldwide; these are obviously something that they have to take seriously. In analysing actual catastrophes that occur worldwide they have, as re-insurers, been able to access all the data; and they have used it to look at trends. Of course, natural catastrophes can occur in the geological zone — there was the devastating tragedy that occurred in Japan on the north-east coast, and there are many others. Munich Re has analysed these and other natural catastrophes from geological sources and finds they show no trend at all, absolutely nothing. The incidences increase and decrease a little bit, but the average incidence is pretty much flat.

By contrast, when they analysed the incidence of catastrophes that have occurred in the world that are weather-related, whether it be storm, flood, drought or other weather-related incidents including large wild fires and so on, these come out as trending upwards, trending fast upwards. This means that it is not just the scientific community, but actually a business community saying that climate change is happening.

Agriculture challenges

My talk tonight is about agriculture. Very early on in my tenure when I took over as Chief Scientific Adviser in 2008, in January, we were seeing for the first time an increase in agricultural prices. This was a change from the real decline that had been happening for something like three or four decades. I recall having various conversations with our agricultural economists at the time, who said the supply side would solve it. 'The price is high; more crops will be planted; this is a one-off event. We will be seeing inevitable decline in real prices. We know what we're talking about.'

In a sense I wish they had been right but they were manifestly wrong. There was a decline in prices post 2007–08, but also by 2010 there were climate-related increases. The massive drought and wildfire and heatwave that occurred in Russia and the Ukraine, followed by — and indeed driven by exactly the same blocking weather pattern — major floods in Pakistan and a mix of drought and floods in China, pushed cereal prices up to far above even the 2007–08 level.

We are seeing it again this year. The drought in USA is putting corn prices up and I think there is now overall recognition that we have a real problem with agriculture. We must think about issues of food security. It is no use taking the moral high ground and saying that as a developed economy we should be thinking how to help. There is a definite potential for high food prices to destabilise whole countries. There has been an analysis which looked at the index of food prices and related it to civil unrest in cities — and of course the world is increasingly made up of cities, as I said earlier. These are trends that are happening.

When food prices go up, even if we did not worry about that from a 'humanitarian' point of view, we should worry about it from a selfish point of view. Think of those thousand cities in Africa of 500,000 people each, in 2025. Think of the potential unrest if they are not getting a reasonable supply of food for reasonable amounts of money, let alone supplies of water and other necessities. City dwellers have political power and they have the potential to draw attention to themselves. Food prices could be a problem.

They are a problem now, because we are not starting equally. We start from a situation where there is fairly dire poverty for around a billion people who have insufficient food intake to even cover their natural energy requirements and certainly not their development. A further billion people are essentially getting insufficient diets, so that they suffer malnutrition and they experience stunting both in mental and in physical growth. This is the starting point, and it is in a context of massive population growth and the growth of the middle class.

We cannot think about agriculture and food security without thinking about water and without thinking about energy. There will be unsatisfied demand, and, as an approximation, by about 2025 or 2030 we will need around 40% more food, 40% more water, and rather more than that in terms of energy, not just to meet the reasonable aspirations of the developing world but also to make improvements.

It is an awkward problem because, as individuals move out of fundamental poverty and become wealthier, their habits change. The demand for livestock and the demand for dairy products rise with gross domestic product, as also do the demand for energy and the demand for access to clean water supplies.

That is the situation that we are faced with now, and I do emphasise the need for speed. You know by 2050 many people will be quite old, so they may not care about it, but for younger people and young children, the world in the year 2025 is going to be a dramatically different world from the one we live in now. So we need to be thinking about that and the challenges leading to 2025.

What are those challenges? In my job, being responsible for science and engineering in the UK, world hunger is an issue. We need to be thinking about reducing the challenge of hunger by thinking about interventions that we can do.

As some of you may know I commissioned and published a report on the future of food and farming[1], which came out year or so ago in the UK. It put forward some sensible ideas about how we could improve our science and engineering to help agriculture. A few things are obvious: for example, the arithmetic shows that yields need to increase significantly faster than in the last three or four decades. Unlike the situation in the 20th century, land now cannot be made available for agriculture by cutting down forests and ploughing in grassland. That is not the world we live in now — and properly not.

[1] Global food and farming futures (2011). Foresight Project. Government Office for Science, Department for Business, Innovation and Skills, United Kingdom. http://www.bis.gov.uk/foresight/our-work/projects/published-projects/global-food-and-farming-futures.

How are we going to increase yields? There is a whole mix of things that could be done. The solutions are not just 'hi tech'. There could be very large benefits in relatively simple changes to the storage of food, for example. Wastage of food is approximately equally a result of pests and diseases pre-harvest in parts of the developing world, and wastage post-consumption in the developed world.

Both types of society waste 40–50% of growing crops. The losses that result from pests and diseases should be solvable by improved storage and infrastructure and credit, and also by simple ways of dealing with stored pests and diseases of crops. In the developed world, however, it is a real problem to reduce the 40–50% of food that is actually bought and then wasted and thrown away. Solving that would be an immense breakthrough. Focusing on waste is going to be really important for food security, and organisations such as CGIAR or IFPRI are doing that and will make some benefit.

An aspect that seems to be almost ignored is the fundamental interrelationship between food production and the food security issue and climate change. We could continue and meet our food security issues using current agricultural practices, but that would be at the expense of enormous increases in greenhouse gases. An international commission that I chaired for the CGIAR climate change system, working with the World Bank, decided that it is essential to be thinking about different agricultural practices. The slogan — which is strangely unpopular — is that we need an agricultural practice which is 'climate smart'. What that means is it can be intensified, that it is sustainable and is operating in a way that does not produce significant amounts of greenhouse gases or use up scarce resources, water being most important. The commission that I chaired reported just in time for the meeting of the climate change group in Durban in December 2011, and I confess I was disappointed that the discussions on climate change did not recognise that agriculture was central to it. Forestry is recognised, and rightly so, but I believe that the world needs to acknowledge the importance of adapting agriculture so that it will meet the requirements of food security in a rather different way. I really feel that is the potential for our future — and it needs momentum.

There are a few things that can be done — applying new technology for instance. We have the ability to do precision agriculture using less pesticide, less fertiliser. We have a better understanding of plant genomics and the ability to use DNA sequencing, not necessarily for genetic modification but for much better plant breeding and selection using markers.

There is a role for genetic modification, GM, but when speaking about agriculture I find people from some portions of the media and members of non-government organisations object, saying GM crops are terrible. Again, I would remind you of Stephen Chu's statement that people are entitled to their own opinions but not their own facts. GM is not going to be the silver bullet, as is clearly stated on page 1 of the Foresight Report. That report says GM crops will be part of a whole mass of solutions for solving the food security problem.

An area that is extremely important and closely linked to agriculture, and indeed climate change, is the issue of water scarcity. We are looking at potential

catastrophe in some areas of the world. There is an enormous reliance in particular parts of the world on aquifers. We can now assess the over-exploitation of aquifers, using satellite technology, and it is quite frightening.

A large amount of underground water has been found in Africa. If ways can be worked out to properly harvest that in a sustainable way, there is potential to supply that burgeoning African population increasing by 500 million in a few years — by using groundwater. It will involve investment, but ways to manage the water resources must also be considered. Where is there better expertise for managing water resources than here in Australia?

That is the challenge for the next 13 years, to 2025. What about 2030 and beyond?

Greenhouse gases challenge

In the next 13 years or so we must deal with two profound tipping points. First, as we know, energy demand is increasing. Energy demand from the developing world is set to more than double. As we move out to 2030, 2040, 2050 it will get greater still. That is going to put pressure on climate change. If we do not achieve a reduction in greenhouse gases in the next two decades — and a significant reduction — there is very little chance of the world meeting the two-degree target that the world community adopted in Cancun, and later at the Durban meeting. It is just not feasible. It is almost too late already.

For that tipping point, we not only will have to address and adapt to the climate change that is with us now — determined by gases already in the atmosphere — but we must also be thinking about cutting greenhouse gas emissions. 'Climate smart' agriculture is one way of dealing with it. We also need fundamentally new attitudes to the way we use energy and our methods of energy production. Otherwise, we will be moving into a different regime. Believe me, the climate projections I see for the world with a three-degree or four-degree temperature rise are profoundly concerning. It is very hard to imagine today's civilisation operating in anything like the same way in a world that is four degrees warmer.

Yes, there are uncertainties with climate change. The UK Met Office's Hadley Centre has made around 50 assessments under different scenarios, from the most pessimistic to the most optimistic. In the most pessimistic, we can expect average temperatures to be higher by three-and-a-bit degrees by about 2060 or 2070. In the most optimistic, those averages are expected by around the year 2100.

So, either way, we have to act now, and it is so difficult. The international community may have decided on a two-degree target, but they are not making any decisions about how the greenhouse gases can be reduced. It may happen. It is urgent.

The second tipping point during the next 13 years is not talked about much. It is to do with population. I said above that there will be another billion people on the planet in the next 13 years — but not all projections agree. The demographers' current best estimate is that at a world population of about

nine or nine-and-a-half billion there may be some level of saturation of human population-growth. It is based on an assumption that there will be a decline in female fertility, similar to the decline seen in the last decade or so.

If female fertility does not drop in some of the countries of the world where there is very rapid population growth, then by the middle of the century and later, the population will be significantly greater.

We know, from research by sociologists and medical people, that the major factors in female fertility are prosperity, the education of women, and the availability of contraception. Unless those factors become more universally available, the world stands again at a tipping point because of the time delays. We need to reduce fertility between now and 2025 or else the population trajectory will lead to significantly more than the forecast nine billion.

These issues are hugely important, but I have a belief that the tremendous resources in human ingenuity and in human moral worth can be harnessed. This conference has recognised that there are vital questions to be asked, and has spoken of actions and solutions that can be achieved. I think there is enough goodwill in the communities around the world to try and make those work. I do hope they do.

Professor Sir John Beddington is Government Chief Scientific Adviser (GCSA) to the UK Government. Since being appointed to that post, on 1 January 2008, he has led in providing scientific advice to the UK Government during the 2009 swine flu outbreak and the 2010 Icelandic volcanic ash incident. The GCSA has also been responsible for increasing the scientific capacity across Whitehall by encouraging all major departments of state to recruit a Chief Scientific Adviser. Throughout 2008 and 2009 the GCSA promoted the concept of a 'Perfect Storm' of food, energy and water security in the context of climate change, gaining considerable media attention and raising this as a priority in the UK and internationally. Prior to his appointment as GCSA, John Beddington was Professor of Applied Population Biology and headed the main departments of environmental science and technology at Imperial College London. Sir John's main research interests are the application of biological and economic analysis to problems of natural resource management.

Opening Address

Senator the Hon. Bob Carr
Minister for Foreign Affairs

I am glad to be here to open this conference in the twenty-fifth year since the Crawford Fund was established.

I have just returned from the United Nations General Assembly in New York, where food security was, of course, of concern.

Around one in seven people in the world lack sufficient food — one billion people. The world must find a way to feed not only these people, but also the two billion more to be added to the world's population by 2050.

Recent crises in Africa show we have a long way to go. Over 18 million people are at risk of food insecurity in the Sahel region of West Africa (in Niger, Mauritania, Chad, Mali, Burkina Faso, Senegal, Cameroon, Nigeria and The Gambia). More than one million children are at risk of severe acute malnutrition. That means stunting. That means learning disabilities. It means premature deaths. In the Horn of Africa, some 16 million people in Sudan, South Sudan, Somalia, Ethiopia, Kenya, Djibouti and Rwanda do not have a reliable supply of food.

A great part of the challenge is how to better manage our resources. Improving food security globally will require a suite of measures. It is about aid, trade, investment and governance.

Our support for women is particularly important. Most food is consumed where it is produced; it is produced by smallholders, and most smallholder farmers are women. At the recent United Nations General Assembly Hillary Clinton emphasised this:

> *We must be focused on supporting women in agriculture, because women often do the work at every link of the agricultural chain: they grow the food, they store it, they sell it, and prepare it. So we must ensure that women get the support they need if we are serious about improving food security.*

Women make up 43% of the agricultural work force worldwide, and as much as 70% in some countries. Often working longer hours than men, rural women are also the caregivers who look after children, the elderly and the sick. Many rural women are small business entrepreneurs and investors who dedicate most of their earnings to their families and societies.

So that is one thing we have to think about in any effort to feed the hungry. Women bear the greatest burden of food insecurity — but they also offer an important part of the solution.

Our aid program is working to address this. We have just established the first African office of the Australian International Food Security Centre, in Nairobi, Kenya. The new Centre is going to help Africans go from a reliance on emergency food aid to building a viable smallholder farming sector.

With a majority of smallholder farmers being women, this work will focus on them.

It is going to deliver research projects across eight countries in the south-eastern Africa region — Burundi, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania and Uganda. These are among the worst in Africa when it comes to accessing reliable sources of food. I am drawn to the simple smart approaches, and the long-term view here.

We are running a project to get farmers to grow trees on their farms. Crop yields can be doubled and livestock have better access to food if the right trees are planted and managed in the right way. This is already working, through an Australian-supported program in West Africa. By planting the right trees, farmers help grazing animals survive through the sometimes eight-month long dry season, feeding on leaves.

We are looking at ways to set up irrigation systems: getting reliable water into these parts of Africa will unlock agricultural potential.

We are looking at integrated farming — vegetable, poultry and cropping.

We have our own history of environmental challenges, insights into irrigation, into how to get the best out of our landscapes, sometimes learned the hard way. We are in a strong position to lead on this.

Doing great research, sharing it, applying it — that is what John Crawford was about. That is what will allow us to better manage our resources and build agricultural capacity and, ultimately, make sure everyone has enough to eat.

It is my pleasure to open the Crawford Fund's 2012 Annual Conference.

Australian Foreign Minister Senator the Hon. Bob Carr was sworn in to the Senate and Cabinet on March 13, 2012. Previously, he had been the longest continuously serving Premier in New South Wales history, elected in March 1995 and retiring from politics over 10 years later in 2005. As Premier, Bob Carr introduced the world's first carbon trading scheme and curbed the clearing of native vegetation as an anti-greenhouse measure. He was a member of the International Task Force on Climate Change convened by Tony Blair, and has received the World Conservation Union International Parks Merit Award for creating 350 new national parks. He is the author of *Thoughtlines* (2002), *What Australia Means to Me* (2003), and *My Reading Life* (2008).

KEYNOTE ADDRESS

The scramble for natural resources: How can science help?

Dr Frank Rijsberman
CGIAR Consortium

Abstract

Humanity is facing its greatest challenge. To produce 70% more food by 2050 without destroying the environment means doing much more with less. Partly due to the abundant food and record-low food prices achieved by the Green Revolution, overseas development assistance for agriculture dropped from over $20 billion in the 1980s to as little as $3 billion in 2006. Stagnation in the yields of major crops such as rice, wheat and maize followed, and the status quo finally crumbled with the food prices and price spikes of 2008, 2010 and 2011. Today large segments of the global population are threatened by the depletion or degradation of natural resources. Making a bad situation worse, climate change further threatens agriculture by increasing the risk of droughts and floods, affecting temperatures and crop growing seasons and altering the distribution of pests and diseases. Agriculture holds enormous potential to reduce poverty in the developing world, strengthen the sustainability of our global food system, and rebuild and revitalise fragile communities so they can move from dependency to self-sufficiency. A holistic approach is now needed to take scientific innovations and move them along the chain into farmers' hands and people's stomachs. No one organisation can achieve that alone. This paper highlights how science has helped in the past, and outlines what it is going to take to boost agriculture in the future. Science is and always will be the backbone of CGIAR work, but now CGIAR is geared up for 'science plus'. CGIAR is aggregating resources and disciplines as it works side by side with partners to reduce rural poverty, improve food security, nutrition and health while sustainably managing natural resources.

This paper addresses four main points. First, the 'scramble for natural resources' that has set up a challenge for agricultural research and development. The paper focuses on land and water, because agriculture is the largest user of both these natural resources and is therefore driving the scramble for them. Secondly, the paper addresses the question posed in the title, and outlines the state of agricultural research and development today and how science can help. Then it discusses the potential to reinvigorate agriculture by kick-starting the science and technology-based engine of innovation that it needs; and lastly it explains CGIAR's contribution to that process.

The scramble

In 2006, a press release issued by the Crawford Fund quoted me as saying, 'We will not run out of bottled water any time soon, but some countries have

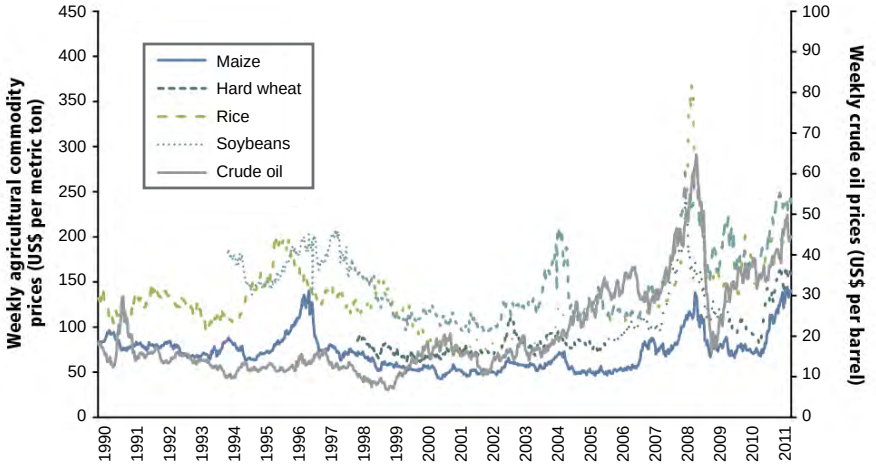


Figure 1. Spikes in food and oil costs: inflation-adjusted prices of maize, wheat, rice, soybeans and oil, 1990–2011, in US dollars per tonne of food (left) and per barrel of oil (right). Source: IFPRI.

already run out of water to produce their own food.' Two years later, the world was shocked by what some people call food price spikes, but which were really part of an upward trend (Figure 1). That started the 'scramble for natural resources', also known as the 'land grab'. A World Bank study published in 2010 shows that some 50 Mha of land changed hands in a short period of time, much of that in Africa. As a result, food security is right back at the top of the agenda, where it has not been for quite a long time.

Of course, this is not the first time that world population has exploded in the last 150 years; nor the first time humanity has faced the challenge of finding enough food to feed a rapidly growing population. The traditional solution during the last century and a half has been to develop more resources by expanding the land area under agriculture and by using more water. For example, in the 1850s, new frontiers were pioneered in the American west, while agriculture continued to expand in Europe and in Australia. However, by the middle of the last century my native Holland had run out of land for that purpose, and so after the Second World War several generations of farmers' sons emigrated to places like Australia, Canada and Brazil.

The Green Revolution

In the 1960s and the 1970s there were places where people had no more space in which to develop more resources. As a result, the Green Revolution, with which CGIAR is closely associated, was all about intensification: about increasing the amount of food that could be produced from the same amount of land.

Norman Borlaug, who is remembered as the Father of the Green Revolution, holds a special place in the history of CGIAR. Along with researchers from the

In developing countries, most small-scale farmers are women.

International Maize and Wheat Improvement Center (CIMMYT), he helped develop semi-dwarf, high-yielding varieties of cereal grains. Together with increased fertiliser use and massive investments in irrigation, these varieties led to the doubling of yields and abundant supplies of cheap food in Asia, Latin America, the Near East and the Middle East. Billions of people escaped starvation, but the increased yields also led to complacency, neglect and a drop in support for agriculture for several decades.

Humanity's greatest challenge

The Food and Agriculture Organization of the United Nations (FAO) estimates that world population is likely to grow from 7 billion to more than 9 billion people by 2050. Moreover, people with rising incomes tend to change their diets and eat more meat. However, to produce a hamburger requires, first, quite a bit of cattle feed, thereby using more resources than are required for a plant-based meal providing the same amount of energy. So the total amount of food needed grows even faster than the population. As a result, the world will need to produce about 70% more food by 2050, preferably in a way that does not wreck what is left of the environment.

Another FAO estimate indicates that at least 75% of that 70% increase will have to come from land already being used for agricultural purposes. There is some space to expand agriculture in Africa and possibly the Amazon, but science now needs to find a way to increase food productivity by about 50% by 2050 — without using more land and water.

That increase is unlikely to come from the commercial farmers in Australia, or from farmers in the Netherlands or in Nebraska, who are already producing almost optimum yields. It is likely to come from the people who currently experience low yields: the small-scale farmers in developing countries, the majority of whom are women, in places where the food grown is also consumed. And it needs to happen in a climate-smart way. This is the focus and mandate of publicly funded agricultural research.

The largest group of researchers in that arena is at CGIAR, which I have the honour to represent.

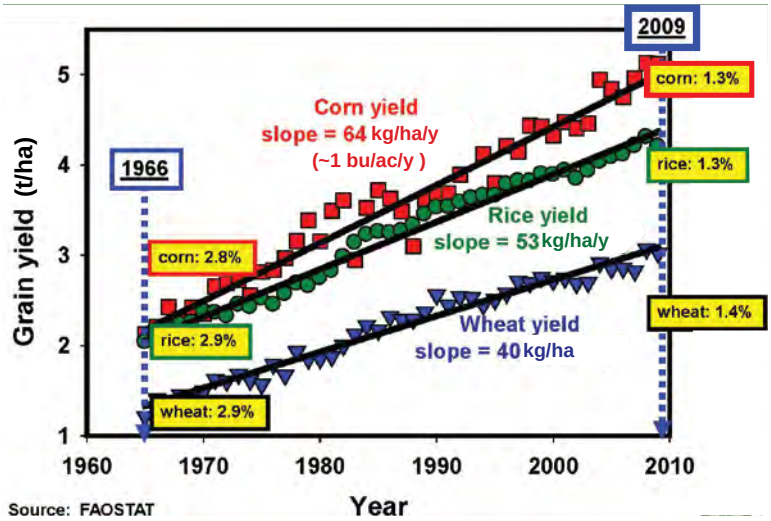


Figure 2. Global cereal yield trends, 1966–2009.

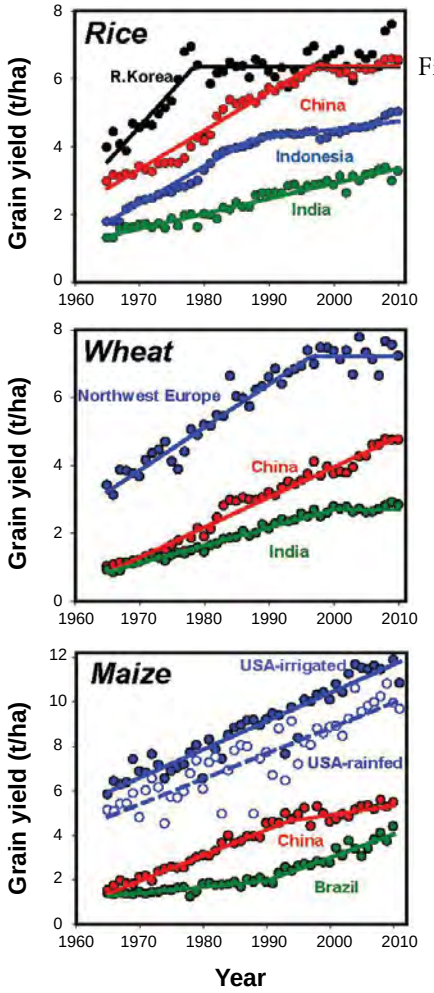


Figure 3. Plateaus in yields of major grains.

Is it possible?

Yields of key cereals have actually gone up steadily over the last five decades (Figure 2). Similar annual yield increases of 40–60 kg/ha were achieved in the 1970s in relation to a much smaller base yield. Those actual yield increases then were equivalent to around 3%, while now they equate to slightly more than 1%. That rate of increase is not enough to sustain future populations.

In addition, there are worrying data, such as those obtained by Kenneth Cassman, Chair of the CGIAR Independent Science and Partnership Council, which show that rather than continuing to increase steadily the yields for rice, wheat and maize are plateauing or levelling off (Figure 3). Obviously such a trend will magnify the challenge of increasing crop productivity.

What caused this? Probably complacency, the neglect of agriculture almost everywhere, and a drop in agricultural support for decades.

Improving productivity

Researchers at the International Water Management Institute (IWMI) are working with the CGIAR Challenge Program on Water and Food near rivers such as the Volta, Limpopo, Nile, Mekong, Niger and others. They find that water productivity (food yield per unit input of water) is very low in a number of river basins. Indeed, the current cereal productivity is 0.2–0.5 kg rather than the potential 1–2 kg/m^3 of water used, in several basins that together are home to more than a billion people and more than 50% of the poorest people in the world.

In a way, that is good news. It suggests there is potential for better yields.

As an illustration, consider rice productivity in good and less good growing conditions. At the International Rice Research Institute (IRRI) in the Philippines there are fields that in mid-2012 were producing three crops of rice a year, with each crop yielding about 7 t/ha. That is a total of 21 t/ha/year from the same piece of land. These crops are cultivated under ideal conditions: fertile soils, plenty of water and a meticulous crop management strategy. Just outside the gates of IRRI, farmers achieve only two crops per year, each of about 4 t/ha, or 8 t/year rather than 21 t/year. As another example, in Africa the smallholders who grow rice in rainfed upland valleys may get only one crop of 2 t/ha/year.

These latter situations offer potential. The farmers might have problem soils, and no access to fertiliser, and no money to buy fertiliser. They might not have seed companies bringing them new seeds, or roads to take their product to market. Their governments might not have extension policies that can help them be part of the value chain that could enable them to process their rice.

This means that there is a whole series of things that can be done to help lift yields, although none of them is necessarily easy. Even where yields are only 2 t, the reasons are not immediately obvious. Many of the low yields in Africa are caused by disease, and science will be needed to help develop new crop varieties that are disease resistant. This will require a constant effort. It will also require a massive effort to put in the roads and the other infrastructure that farmers need so they can be more productive.

Nevertheless, there is hope associated with a crop yield gap, because of the tremendous potential in science today to help close it.

What is the potential?

Two trends are having a big impact on science for tomorrow's agriculture. First, there is the life science revolution that is being propelled by molecular biology. Although in many ways molecular biology is still just at the beginning, it has changed the way that scientists do business, both in CGIAR Centers and Programs and with their partners, in the last ten years. More about that later.

Second, there is the information technology revolution, which is relevant not just to Australian farmers but also to smallholder farmers. For example, laser

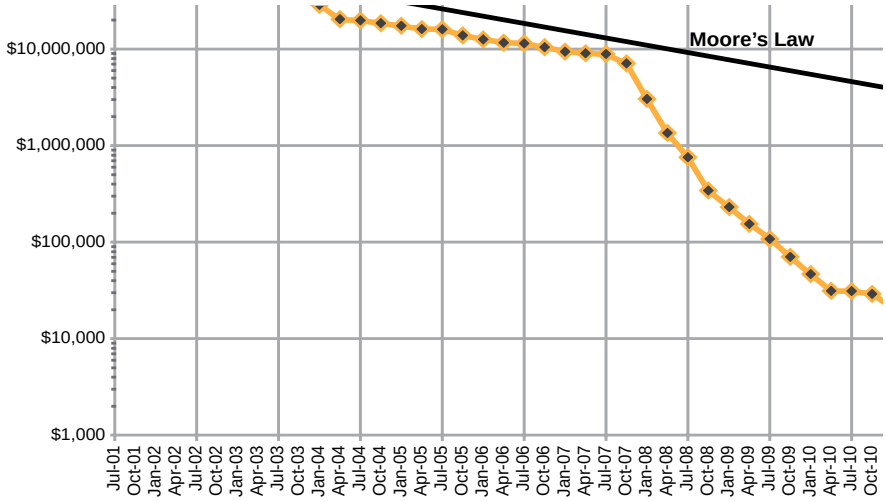


Figure 4. The cost per genome in DNA sequencing (yellow line) is falling faster than Moore's Law's projections of the cost of making computer chips.

land levelling, which offers great potential for water savings and higher grain yields, is becoming increasingly popular with farmers everywhere. More and more farmers are also using mobile phones to access extension services and market information.

It is well known that innovations in the IT and computer science industries are leading to rapid change: consider Moore's Law, which states that the number of transistors on a chip will double approximately every two years. Moore's Law illustrates how fast the cost of making chips tends to fall, which in turn drives the change in that industry.

However, the cost of DNA sequencing is now falling even more rapidly than projections under Moore's Law (Figure 4), enabling tremendous changes in the business of science.

The CGIAR reform process

CGIAR is ready to take advantage of those scientific opportunities. It has been revitalised recently, particularly in comparison to its condition in 2008.

At the start of 2008 the CGIAR system, though relatively well funded compared to many national systems in Africa, was stagnating. It had no new scientists, no new laboratories, and little core support for the sort of strategic research that incurs high overhead costs. As an example, the budget of one particular CGIAR Center in 2006–07, after making adjustments for inflation, amounted to only half of its 1995 budget peak. This is not the vigorous type of institute required to take advantage of the potential in science and deliver much-needed increases in productivity.

Since 2008, through initiatives of the Centres and CGIAR's donors, there have been several years of reform. CGIAR has been renewed and now has fresh

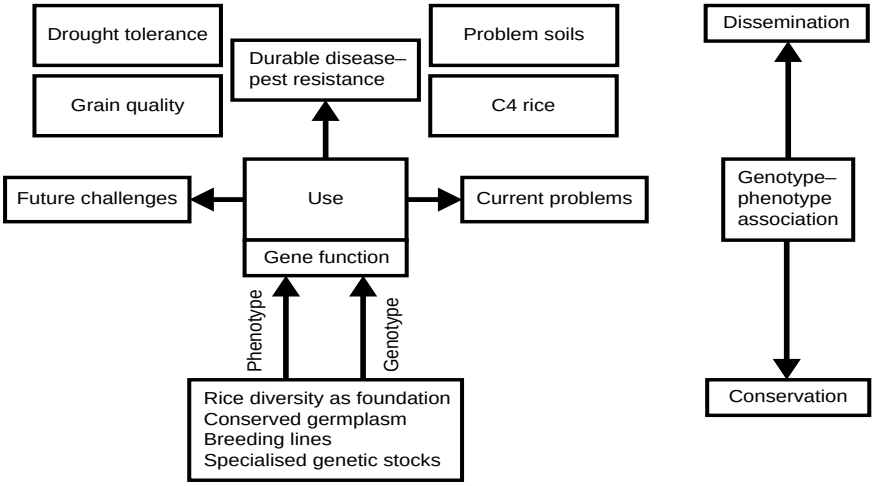


Figure 5. The genetic diversity research platform in CGIAR.

vigour and infrastructure. IRRI, for example, has received a large grant from the Australian Centre for International Agricultural Research (ACIAR) to build new labs and buy new equipment, and several other Centers have grown 30–40% in 2012. Now the potential is available to take advantage of the opportunities that science offers.

Countries like Australia are tending to support publicly funded research in agriculture. The International Food Policy Research Institute (IFPRI), a CGIAR Consortium member, estimates that it would take an investment of US $1 billion in 2015 to generate an extra 0.5% increase in productivity per year, to try and meet the challenge of feeding our increasing population — and, surprisingly, funding appears to be available.

CGIAR research agenda

There is now a coherent agenda across the CGIAR system, through 16 research programs implemented by the 15 Centers and hundreds of partners. Plant breeding is still at the heart of that agenda. There are also programs that focus on how innovation reaches farmers through farming assistance, all of which take into consideration natural resources management, climate change and health.

Genetics cuts across all the CGIAR Programs (Figure 5) though CGIAR has no program devoted to genetic research. Genomics and genotyping are overtaking classical breeding techniques, with molecular breeding forming the basis of much of the work carried out by the Centers today.

Phenotyping — the labour-intensive process of going out to the field and seeing whether certain traits are expressed in a particular plant — is still part of the work. IRRI is trying to automate that in a way that will help in discovering new genes, to address a series of challenges even more efficiently.

Making rice climate-proof. Experimental plots of rice showing degrees of drought resistance (left) and salinity resistance (right).

Whereas ten years ago it was just a dream to be able to apply molecular breeding to understand the genetic diversity residing in genebanks, today it is a reality. This means that Centers like IRRI are now not only breeding plants that have higher productivity or are disease resistant, they are also breeding plants that are resistant to abiotic stresses such as drought.

Ten years ago, plant breeders were restricted in developing drought resistant crops because classical breeding techniques were not suitable for the several traits required. Now, a key gene that IRRI has discovered imparts submergence tolerance to rice. IRRI is proud that almost all the hybrid rice varieties today have incorporated this Sub1 gene, and that they are widely available to farmers.

Similar genes that have been discovered can be pyramided to create drought resistance, and there are also key genes that will help with salinity resistance.

These and other breakthroughs have been possible because of CGIAR's genebanks (Figure 6). Genomics is revealing that a lot of the traits that are required are actually already in our genebanks. It is often thought that applying the techniques of molecular biology must result in a genetically modified organism (GMO). Not so. In fact it turns out that traits that confer resistances and tolerances are already within the gene pool and those characteristics can be achieved through traditional breeding, using molecular technology.

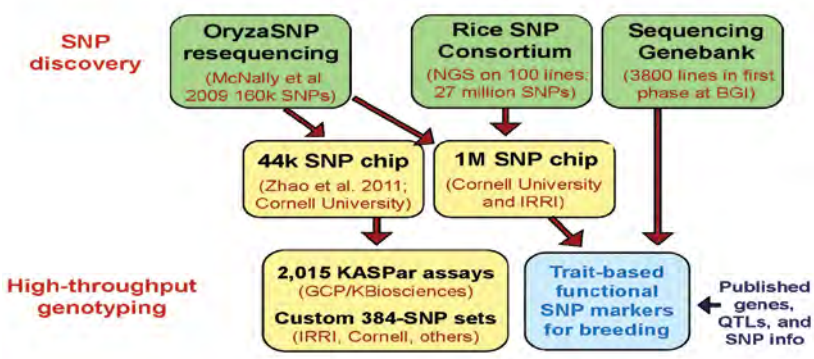


Figure 6. CGIAR has new resources for gene discovery.

The CGIAR genetic diversity treasure-chest.

CGIAR is the custodian of very large collections of plant genetic material with the necessary diversity. The Centers hold the largest collections, relative to their respective areas of work. Together, they hold only 10% of all the accessions held in genebanks worldwide, but they are extremely active in using that material. The number of accessions distributed by CGIAR is twice as large as all the distributions from other genebanks combined, according to our data. As importantly, the material in the genebanks is used extensively within CGIAR.

More holistic approaches to improve productivity will span from the microscope to the marketplace. These are approaches that not only integrate the latest science and technology to breed better varieties, more quickly, but also use effective strategies to get those varieties to small-scale farmers. Examples include creative partnerships with government and private partners to ensure a sufficient supply of clean, affordable seed. They may include better use and integration of biodiversity for breeding programs, to diversify diets, or to take advantage of natural pest predators and resistance. Or they may involve the identification and boosting of natural nutrients in crops using biofortification.

In economic terms, several analyses have estimated the returns on investment in CGIAR to be considerable. Even the most conservative estimates show a 2:1 ratio of returns on investment in CGIAR Research Programs — with many indicating far greater benefits to costs, as high as 10:1 in some cases.

More than 7000 improved varieties have been developed, as public-good products. They are made available free of charge to national agricultural research services — which are the entities that release new varieties in each country — and to academic and other agricultural development institutions to support further advances in food production. Worldwide, 60% of all land planted with improved varieties includes varieties produced from CGIAR Centers.

Benefits to Australia

While CGIAR focuses on serving people in the developing world by helping them improve their agricultural productivity, the development aid CGIAR receives often has a spillback effect that benefits some donor countries. For example, in Australia, which ranks among the top ten wheat-producing countries in the world, as much as 98% of the area sown to wheat is growing varieties developed by CIMMYT. These include semi-dwarf varieties developed in the

CGIAR Programs and Centers have helped make orange sweet-potatoes, rich in vitamin A, more available for childrens' diets (left), and have invested in commercial cultivation of sea-cucumbers (right) in Vietnam and several islands near Australia.

1970s and, more recently, varieties that have genetic material built into them to make them resistant to wheat stem rust. Such crops are estimated to have increased the value of outputs from the Australian wheat industry by at least US $750 million. Indeed, assessments indicate that the benefits to Australia are as high as Australia's investment in the CGIAR system.

Impact of CGIAR research

CGIAR research generates more than just publications. It puts real benefits into the hands of farmers, and the Centers are getting better at making sure that their innovations reach the farmers who need them.

People are influenced not just by increasing productivity; they are also interested in the links to health and in growing crops that have higher nutritional value. For instance, programs that promote the orange-fleshed sweet potato, which is rich in vitamin A, should have a major impact on child health. In sub-Saharan Africa and in Asia, vitamin A deficiency is a major health problem, particularly for very young children and pregnant women. It contributes not only to higher rates of blindness, but also to premature death and disability.

Elsewhere, ACIAR and the WorldFish Center have joined forces and have been investing in the commercial cultivation of sea cucumbers in Vietnam, the Philippines, Solomon Islands, New Caledonia, Fiji and Australia since the mid 1990s. In Vietnam sea cucumbers are grown in shrimp ponds, in rotation with shrimp.

A 2011 ACIAR assessment of the impact of CGIAR work estimated that the benefits of IRRI's rice breeding in just Vietnam, Indonesia and the Philippines was worth about US $1.5 billion per year from 1985 to 2009.

Conclusion

Yes, the food price spikes in recent years have led to a scramble for natural resources, such as land grabs in Africa, but they have also put food security back at the top of the agenda. Science can help the world grow more food using less land and less water, thereby limiting humans' natural resources footprint. CGIAR has a promising agenda that harnesses the potential of science to feed the

world's growing population. It is pleasing that this work also benefits Australia, which is a valued and strong supporter of international research and agriculture through ACIAR and AusAID.

References

McNally K.L., Childs K.L., Bohnert R., Davidson R.M., Zhao K., Ulat V.J., Zeller G., Clark R.M., Hoen D.R., Bureau T.E., Stokowski R., Ballinger D.G., Frazer K.A., Cox D.R., Padhukasahasram B., Bustamente C.D., Weigel D., Mackill D.J., Bruskiewich R.M., Raetsch G., Buell C.R., Hei Leung & Leach J.E. (2009). Genomewide SNP variation reveals relationships among landraces and modern varieties of rice. *PNAS* 13. doi: 10.1073/pnas.0900992106.

Zhao K., Chih-Wei Tung, Eizenga G.C., Wright M.H., Liakat Ali M., Price A.H., Norton G.J., Islam M.R., Reynolds A., Mezey J., McClung A.M., Bustamente C.D. & McCouch S.R. (2011). Genome-wide association mapping reveals a rich genetic architecture of complex traits in *Oryza sativa*. *Nature Communications* 2: 467. doi: 10.1038/ncomms1467

Dr Frank Rijsberman has over 30 years experience as a researcher and consultant in natural resources management in developing, transition and developed economies. He is Chief Executive Officer of the CGIAR Consortium, taking on that position in May 2012 from a position as the director of the Water, Sanitation & Hygiene Division of the Bill & Melinda Gates Foundation. Prior to that he led Google's philanthropic team. Frank served as Director General of the International Water Management Institute (IWMI), one of 15 members of the CGIAR Consortium, from 2000 to 2007, where he initiated the Comprehensive Assessment of Water Management in Agriculture and developed and led the Challenge Program on Water and Food.

Email: f.rijsberman@cgiar.org

KEYNOTE ADDRESS

Can we feed a growing world and sustain the planet?

Professor Jonathan Foley
Institute on the Environment, University of Minnesota

Abstract

Increasing population and consumption are placing unprecedented demands on agriculture and natural resources across the planet. Today, approximately a billion people are chronically malnourished while our agricultural systems are concurrently degrading land, water, biodiversity and climate on a global scale. To meet the world's future food security and sustainability needs, food production must grow substantially, while at the same time agriculture's environmental footprint must shrink dramatically.

This paper outlines a framework for potential solutions to this dilemma, showing that tremendous progress could be made by halting agricultural expansion (especially into tropical forests), closing 'yield gaps' on underperforming lands, increasing cropping efficiency (especially in terms of water and nutrient use), shifting diets and reducing waste. Together, these strategies could help us double food production while greatly reducing the environmental impacts of agriculture.

The scramble for natural resources, the topic for this conference, reflects the fact that agriculture is going to be absolutely fundamental to the success of our civilisation moving forward. It has been so for ten thousand years and it needs to continue to be so for the next ten thousand years, because one of the big challenges for the world is food security.

There are roughly 7.2 billion people on the planet and, depending which estimate you look at, roughly a billion of them are food-insecure and malnourished. Feeding them adequately is already a huge challenge. On top of that, we have to meet the future food demands of the world which are partly driven by the size of the population. The world's present population of 7.2 billion is heading to, at a median estimate, 9.5 billion sometime before 2050.

More important than population growth, though, is that diets are changing. Already here today on this planet, about 4 billion people are becoming richer and joining a global 'middle class'. There has never been a global middle class before. There have been a few rich people and many very poor people, but that is changing. In that transition those 4 billion people are adopting a kind of western diet, with more calories, more meat, more oils and other rich components. It turns out that this change is a much bigger factor than population growth in the demand for food.

Our estimate, which differs from that of the FAO, is that the expected changes in diets and population double the projected global demand for calories by 2050. In other words, in the next 38 years demand will outpace the gains made by all previous agricultural innovations combined.

How do we feed everyone now and also meet the food needs of the future without further disrupting the planet? This is a really serious issue because agriculture in many ways is the biggest disruption this planet has ever experienced, at least during the time of *Homo sapiens*. One reason for that is the extensive area of land devoted to feeding the world.

About 16 million km^2, which is roughly the size of South America, is the total area of the world's land devoted to growing crops. The world's pastures occupy approximately 34 million km^2, which is about the size of Africa. These add up to 40% of the parts of Earth's land mass not subject to ice. Most of the other land is in the Siberian tundra or the northern Canadian arctic, or the rainforest in the Amazon and the Congo and the Indonesian Archipelago — and use of rainforest or desert or arctic areas is not a good solution to the problem of feeding the world.

Agriculture is also by far the world's largest user of water. Depending on how you do the bookkeeping, agricultural production takes up either 70% of water globally or 90% of the consumptive use of water (that is, taking water out of a catchment or 'watershed' and not returning it to the same catchment).

Agriculture is also the biggest source of water pollution globally, not because agriculture is especially dirty but because it is so widespread. Naturally, the activities that occupy 40% of the world's land make very large contributions, in aggregate, to water pollution in lakes, rivers and even coastal waters, mainly in the form of nitrogen and phosphate. That is also of concern.

A further concern is climate change: both how climate change will impact on agriculture, and also the impacts of agriculture on climate change itself. When most people think about climate change they think of fossil carbon, coal, oil and gas being burned and contributing greenhouse gases. Yet it turns out that, of all the economic sectors in the world, agriculture is the largest contributor of greenhouse gas emissions: roughly 35%. Most of that contribution comes from tropical deforestation — in Amazonia, the Indonesian Archipelago and parts of Africa. The second largest contribution is nitrous oxide emissions and methane emissions from livestock, paddy rice and excessive use of fertilisers. The sum of those emissions is very large, and a huge contributor to climate change. To put that into perspective, the emissions from all the worlds' transportation contribute only 15%. Therefore, if you want to stabilise climate change, you first must consider agriculture, before anything else.

That makes three challenges: feed the world, feed the future, address sustainability. Each one of those challenges is daunting, and we must solve all three, and at exactly the same time, over the next 30–40 years. This new combined challenge is unprecedented in human history, and it brings in multiple disciplines and multiple outcomes.

How are we doing so far? In a word, badly.

First, most of the gains in global production in agriculture have not come from land expansion. In the last 20 years there has been just a small increase in the total amount of land put in production. Some of that has occurred in the tropical parts of the world, through deforestation, but agricultural land has also been lost in the mid-latitudes, especially in China, India, Europe and the United States, where farmland has been taken up for suburbs and urban expansion. As a net result there is really not much more land in production.

Gains in production have, instead, been the fruit of the Green Revolution which has increased yields per hectare. Those yields per hectare are not really being sustained, as Ken Cassman[1] and others have been pointing out. In the last decade especially, yield improvements have flattened off in many parts of the world.

Looking at global rice production, in a number of regions during the last decade 2002–12 there has been no statistically significant improvement in yield. The graph of yield versus time has been, essentially, flat in 35% of all the rice-growing regions on the planet. For wheat globally, 40% of productive areas have not increased yield, and that includes Australia. The very severe droughts during that period of time are partly responsible, but the picture is widespread. It is the same in China, India, Europe and even the great plains of North America. These two grains feed more people than all the others in the world combined. Wheat and rice provide over half the world's calories, but in 30–40% of the wheat- and rice-producing areas there has been no progress in yield improvement. This is extremely alarming and very important. The point is that yield improvements cannot be taken for granted; they will need significant investment.

In the United States and much of the rest of the world there is an idea that it is possible to achieve food security and double the production of calories by 2050, just by growing more food. Yet, the current systems are neither improving food security nor keeping up with demand, and, as I have pointed out, they are completely non-sustainable in relation to land, water and climatic resources.

Strategies for security of food supply and environment

I posit that we have to develop entirely new kinds of strategies that think about food security and environmental security together as an interwoven problem. It is a problem that has to be solved not just by growing solutions but by managing the entire system differently. Food security and environmental security are both parts of the same problem — a problem with multiple dimensions.

The world needs to produce approximately double the current total amount of food, and there are also challenges in the distribution, access and resilience of that food production system. The environment is subject to damage that may be several orders of magnitude larger than the sustainable limit. This is the picture today: not enough food security for the future, and excessive harm, even beyond 2050, in loss of biodiversity, deforestation, climate change and other ways.

[1] University of Nebraska–Lincoln; Chair, CGIAR Independent Science & Partnership Council

Can we deliver more food security? Can we perhaps double food access and resilience and availability by mid-century, and dramatically cut the environmental costs of agriculture, so that we achieve truly a world with food security and environmental security together for the first time?

It is, in fact, possible to do that. The strategies outlined briefly here, when put together, might just let us attain a food-secure and environmentally-secure world by the middle of the century. These are abstract ideas at the moment, and it is the job of all of us in this room, and others, to make them practical.

(i) Stop deforestation

First, consider deforestation. The area, the footprint, of agriculture in the world is expanding only through deforestation. There are parts of the Amazon or Kalimantan or West Africa that could be further deforested; yet that process is causing severe environmental disruption. In Rondonia in Brazil, virgin forest is being cleared, mainly to grow soybeans for export, mostly to Europe and China.

Is this a good trade-off, for clearing the last remaining virgin forest of the tropics? There are huge amounts of carbon and unique biodiversity in these landscapes. They are being exchanged for animal feed such as soybeans, or for palm oil, or maybe for timber or beef production. The bottom billion people who are food insecure today never benefit from this large-scale deforestation. The products are not intended for them but for the global middle class, whether in North America or Europe or, increasingly, Asia.

Deforestation now is not benefiting the people who need food. It is badly damaging the environment and while it is increasing wealth it is gaining no real improvement in global food security.

I argue that deforestation is very bad for the planet and it should not happen.

(ii) Intensify production

If the footprint of agriculture cannot be extended, there must be intensification of production on land already cleared, to boost yields per hectare on existing farmland.

There are many many opportunities for this around the world. In the grain belts in North America, western Europe, China, Brazil and Argentina, all good growing regions, yields are already at maybe 80–90% of the current ceiling of yield. There are also regions all over the world which produce a fraction of their yield ceilings, especially in Africa but also in Latin America and even in Europe, especially eastern Europe. Eastern Europe currently produces only 25% of the yield they should be getting. This area was one of the world's greatest 'breadbaskets', but it has been damaged by years of neglect and institutional problems relating to land tenure and ownership, investment, distribution, governance, and other issues. In other places, yield improvements have not begun yet: for example in parts of Africa and other places all over the world. There there are huge opportunities to intensify production.

It is not necessarily genetic factors that limit productivity in most of these places in the world. Instead, the limiting factors may be disease and pests and

also nutrients. Places where yield improvements are genetically limited are mainly the United States, western Europe and possibly parts of Brazil and Argentina. Elsewhere, again and again it turns out that nutrients and water are the keys to improving productivity at the base of the production pyramid: in Malawi for example, and other places. Therefore there is enormous potential for sustainable intensification at the base of the pyramid — but what will that sustainable mode of intensification really be?

(iii) Same water, fewer chemicals

How can food production and nutrition be dramatically improved using no more water and fewer chemical additives?

In much of the world, growers are applying far more nitrogen fertiliser, whether in chemical form or in manure, than plants could ever use. The excess runs away as nitrate, in groundwater or river water. For example, nitrate entering the Mississippi River in the United States flows into the Gulf of Mexico and destroys the fisheries there by making the waters anoxic, devoid of oxygen. There is a similar situation in China and India, the most highly polluting agricultural landscapes in the world per hectare in terms of nitrogen. In all three countries, excess nitrogen also escapes as nitrous oxide (N_2O) into the atmosphere where it is a powerful greenhouse gas. Those losses of excess nitrogen could be cut with no losses to food security, as discussed below. Yet other parts of the world — such as in Africa — need to increase their use of nitrogen, potash and phosphate. This is the ultimate Goldilocks problem: half the world applies too much fertiliser, the other half applies too little, and almost nobody is just right except for maybe some of the Europeans and the Australians.

The same observation can be made for water. The amount of water it takes to grow one calorie of food through irrigation, on average, globally, is 1 L. That means we all, if we are vegetarians, carry around 3000 L of water daily from our irrigation-grown food. However, there are large variations in water-use efficiency. For example, Israel may be two to three times more efficient than that because they use drip irrigation for reasons of water security and national security. Other parts of the world, especially Pakistan, Rajasthan and parts of India, may use three to four or five times more water than the global average. The amounts of water it takes to grow the same amount of the same kinds of crops in similar climates can differ by a factor of 10 or 20 between the best and worst producers. There could be as much as a hundred-fold difference in the water productivity of food systems around the world. Therefore, we see huge opportunities to improve the productivity of water, of nutrients, of energy and other inputs, because there is so much waste in agricultural systems.

There is potential for ten-fold and hundred-fold improvements in the efficiency of agriculture using very simple technologies already in use. This is not inventing anything but instead deploying existing techniques.

(iv) Consider diet, biofuels and food-waste

In the United States there is currently disagreement about whether crops should be used for food production or biofuels — especially ethanol — and also about

food-waste. To balance our existing opportunities to improve food production and supply, it is also vital to improve the demand side of the equation: how foodstocks are used.

In India, China, most of Africa, a lot of Australia, crops are grown to feed people: rice, wheat, cassava, fruits and vegetables and nuts and so on. By contrast, in northern China, most of western Europe and in the United States breadbasket, crops are grown to fuel cars and feed cows. It is true that the cows in turn feed people eventually, with large losses of energy and calories along the way. In an ideal world, human uses would be the top and first priority, and there could also be some crop production for energy and livestock.

There is a real debate about this situation in places like the United States. Only 14% of crops grown in the US breadbasket end up as human calories, mostly in dairy. In the US only 60% of crop production is for food, while 35% is for livestock and 5% for biofuels. On top of that, about 30–40% of food is wasted all around the world. In North America the grain-growing areas grow mostly corn and soybeans; about 40% of that corn is turned into ethanol; about 36% is turned into animal products, mainly.

Some animal production can be quite efficient: dairy for instance. Converting corn and soybeans into milk is about 40% efficient; into eggs, maybe 20%. Producing chicken is quite an efficient process in relation to protein, but less so in relation to calories. So, as the saying goes, the real 'elephant in the room' in this case is a cow! Converting grain calories to meat calories has 3% efficiency, which means 33 kg of corn is used to produce 1 kg of steak — an unsettling situation to consider at table. This system is well established in the US and is spreading to other parts of the world as well.

If a food chain system wastes 97% of the original calories, doubling yield is not likely to make it more efficient. Food-waste undermines the idea of growing more food to feed the world and the future. The supply side of the food chain may be manageable, but it is important to also manage the demand side better.

We can do this!

Overall, applying these multiple strategies — not just improving yield but also taking care with deforestation, taking care with the remarkable material efficiency gains we can see in agriculture, and thinking about diet, biofuels and food-waste around the world — there is more than enough capacity to double the world's calories by 2050 and simultaneously cut greenhouse gas emissions, perhaps by as much as 80%. We could eliminate losses to biodiversity from agriculture, and virtually eliminate unsustainable water withdrawals and water pollution.

I stress again that these goals cannot be achieved with 'business as usual'. We must not think only about improving the yields of crops, nor only of some crops, such as corn, which do not actually feed people in most of the world. We have to think much more broadly than that. New approaches are needed.

New solutions need new mental frameworks as well. It is easy to spend time in ideological mind traps, whether about genetically modified organisms (GMO) or about local and 'organic' food systems. An interesting fact is that most of the food in the world is neither GMO nor 'organic'. Only about 1% of the calories grown in the world are 'organic'. Certified 'organic' crops and genetically modified crops occupy about 10% of the acres of the world in production. That means that 90% of the food in the world is in neither of those categories. They are like a sideshow compared to present-day global food production systems.

While avoiding ideological mind traps and learning how to collaborate, it is also important to identify factors and systems that can assure food and environmental security in the future.

Consider climate change. Two countries — Brazil and Indonesia — and only five commodities produce 15% of the world's CO_2 emissions. Those five crops in two countries are equal to every car, truck, airplane and lorry on the planet added together. Why then is there such a focus on transport? For other greenhouse gases, say nitrous oxide, four countries and three crops produce more than two-thirds of global emissions.

Considering water pollution, those same four countries and only three crops are responsible for two-thirds of the nitrogen pollution to the world's oceans and 75% of the leakage of phosphorus into rivers and lakes. Suitable policies suitably targeted potentially could make a dramatic global difference.

In conclusion, we all know agriculture is central to the success of civilisation. I urge us all to take a broader view and recognise the environment as another central pillar for the future of civilisation. I am convinced that we can solve the problems of food security and environmental security simultaneously and in complementary ways, and in fact I think we have no other choice.

We have to get this right for our civilisation to endure beyond this century.

Professor Jonathan Foley is the director of the Institute on the Environment (IonE) at the University of Minnesota, where he is a professor and McKnight Presidential Chair in the Department of Ecology, Evolution and Behavior. He also leads the Global Landscapes Initiative of the IonE. Foley's work focuses on the sustainability of our civilisation and the global environment. He and his students have contributed to understanding of global food security, global patterns of land use, the behaviour of the planet's climate, ecosystems and water cycle, and the sustainability of the biosphere, and that has led him to be a regular adviser to large corporations, non-government organisations and governments around the world.

KEYNOTE ADDRESS

A global land rush?

Dr Derek Byerlee
International agricultural specialist

Abstract

Recent strong commodity prices have led to rising demand for farmland and this is projected to continue for the medium term because of increasing populations and incomes and growing use of biofuels. Global analysis indicates that about 450 Mha of suitable land may be available to bring into cultivation, much of it in sub-Saharan Africa, Latin America and Russia. Improved returns in farming and relatively cheap land in some countries have translated into a sharp rise in domestic and foreign investment into farmland, largely focused on these same countries with uncultivated land. Investors have been very heterogeneous, with many from emerging countries and some with little track record in agriculture, but supported by rising portfolio investor interest in agriculture. Despite perceptions, governments and sovereign wealth funds make up a relatively small share of such investments. A surprising development, given the long tradition of family farming almost everywhere, has been the rise of corporate 'superfarms' often managing over 100,000 ha of prime cropland. Where land and other markets work well, strong investor interest in agriculture represents an opportunity to tap capital, technology and new markets. However, where land governance is poor and institutional capacity weak, there have been many failures, whether measured in economic, social or environmental terms, especially in Africa and South-East Asia. In Australia, given skilled farmers and strong institutions, there seems little reason for concern about recent reports of foreign investment in farmland. Australia has led the world in arguing for freer agricultural trade and investment and should continue to do so. Increased transparency through a register of such investments could alleviate fears in some circles of a foreign 'land grab' in Australia.

'Land rush' — the term reflects the late 1800s when land was being allocated to settlers in Oklahoma. The 1893 land rush was for the last big area of land being opened by the US Government under the Homestead Act, intended to allow easy access to land by families. While negotiations were taking place, albeit with rather unequal terms for the indigenous owners, tens of thousands of people lined up on the border with Oklahoma, waiting for the negotiations to be completed. Then at midday on 16 September 1893, on the firing of a starting pistol, they set off in a race, and the first one to reach a surveyed block was able to claim that piece of land.

As the human race closes in on the global land frontier today, it is worth wondering if it is entering a somewhat similar chaotic situation, in terms of allocating the land that remains available at the global level.

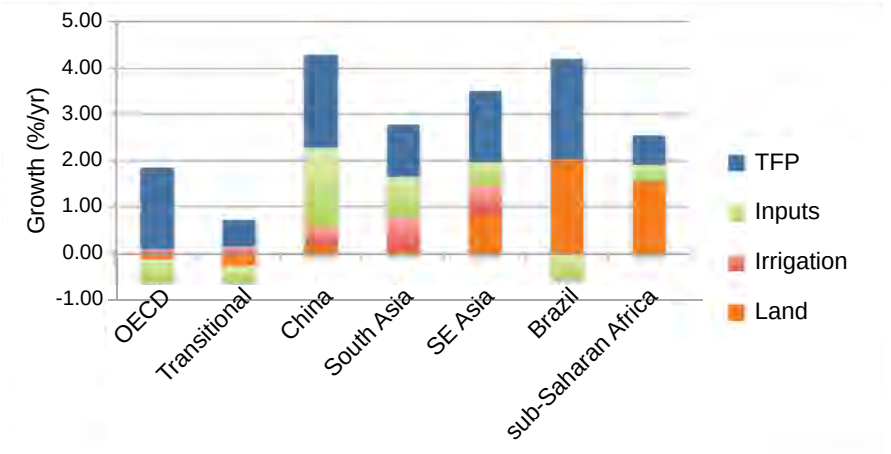


Figure 1. Sources of agricultural growth, by region, 1961–2009 (Fuglie 2012). TFP = total factor productivity.

This paper discusses first the supply of and demand for land for cropping; then focuses on investment in farmland — particularly large-scale investment — and some of the opportunities and risks associated with that, including in Australia; and finally it looks at some of the policy issues.

Over the last 50 years or so, the big increases in agricultural production have come through improved productivity, especially the productivity of land. Figure 1 shows how agricultural growth over the last 50 years can be divided between expansion of the land area in use and growth in yield, with yield growth further decomposed into input intensifications and growth in total factor productivity (TFP). In three regions, land expansion has been a significant source of agricultural growth: South-East Asia, Brazil and sub-Saharan Africa. Of these, sub-Saharan Africa is particularly problematic because even though agricultural growth there has recently accelerated it is still largely as a result of using more land, rather than through improved productivity.

Looking to the future, how much land can be expected to come into production for cropping? (Pasture land is a separate issue and available data are of poor quality.)

Currently, about 1500 Mha (1.5 billion ha) of land is used for crops. By 2030, estimates made for the World Bank suggest that an additional 120–240 Mha will be needed, for a range of crops including biofuels (Deininger et al. 2011). That estimate does not allow for current cropping land being turned to other purposes in the future, such as urbanisation (Lambin & Meyfroidt 2011). Conversion of cropland to urbanisation and infrastructure could account for as much as 50–100 Mha.

Both cropland and pasture, in unknown proportions, are also being lost through degradation, and those losses are estimated at 30–87 Mha, a significant amount.

Table 1. Potential availability of uncultivated land in different regions (Deininger et al. 2011).

	Currently cultivated area (Mha)	Uncultivated area suited to cropping (Mha)
Sub-Saharan Africa	221	201
Latin America and Caribbean	164	123
Eastern Europe and Central Asia	254	52
East and South Asia	454	15
Middle East and North Africa	97	3
Rest of world including Australia	360	52
Australia	46	26
World total	1554	449

In summary, while a substantial amount of extra cropland will be needed, the amount is unclear because of uncertainty about how yields may improve in future, about developments in 'second-generation' biofuels and their need for land, and about how much trade will shift patterns of production to more land-abundant regions, as expected in a liberalised regime.

The next question is how much land is available. Deininger et al. (2011) using the database of IIASA* mapped out the land that was of medium to high potential for crop production and currently uncultivated; it was neither forested nor protected, and had a population density of fewer than 25 persons/km^2. They found that in total there may be about 450 Mha of land with those criteria which potentially could be brought into production (Table 1) — much less than FAO predictions (e.g. Alexandratos & Bruinsma 2012). However, that available uncultivated land is in a relatively few countries: several in sub-Saharan Africa, in Latin America — mainly Brazil and Argentina — and in Russia. The estimate also included around 20 Mha in Australia that might be brought into cultivation (Deininger et al. 2011).

Much of that land, particularly in sub-Saharan Africa is in areas with very poor infrastructure such as roads, and far from ports, which will reduce the profitability of cropping. It may also have unsuitable soils — a situation not captured in a global analysis; much of the apparently available land in Australia seems to be in that category.

Looking at both the predicted demand for land for both farm and non-farm uses, and the estimated land available, it appears the world is approaching the 'global land frontier', in terms of land that might be brought into production.

Investing in land

Land costs money, and it has differing values according to the region. In Australia and much of Latin America there are private land markets, but in many countries, particularly in South-East Asia and sub-Saharan Africa, private land

* International Institute for Applied Systems Analysis, based near Vienna.

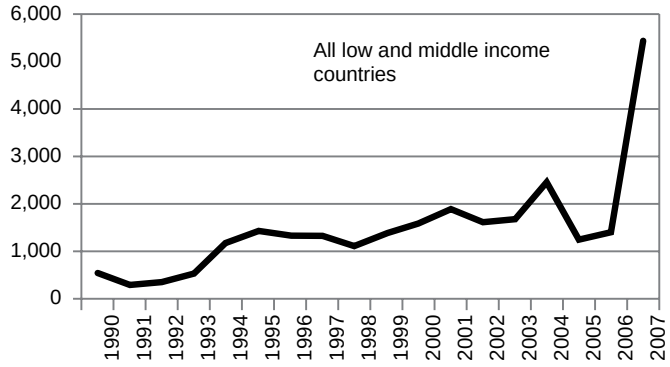


Figure 2. Flow of foreign direct investment (FDI, US$ million) in farming, stimulated by higher commodity prices especially since 2005 (UNCTAD 2009).

markets are not well developed, and many of the large concessions are being negotiated through government.

Even standardising for land quality in terms of potential crop yields, the annual rent for land capable of producing 3 t soya bean/ha varied very widely in 2010. In Mozambique that land would have no market value, because there is no land price there and the land has been allocated to companies through government mediation for about US $1/ha. In the Ukraine also, land markets work very poorly and the rent would be about US $30/ha/year. In central Brazil, the low rental price (around US $60–80/ha/year) is largely a factor of high transport costs from the interior to the port. By comparison, in Iowa farmers would pay $450/ha/year for land of this quality.

Based on information from Savills** (2012) annual report on farmland prices, Australia has relatively low-priced land and there are potential returns from investing in farmland. Again, standardising for quality using crop yields, the cost to buy land to produce a tonne of wheat in Australia was around $900 in the Savills (2012) report — one of the lowest in the world.

With those sorts of land-price differentials between countries, investment flows going from one country to another are expected. In a situation of land scarcity, investors would be looking for low cost (or lower cost) land. However, the available estimates and statistics are weak in this area. UNCTAD, the United Nations Conference on Trade and Development, collects partial information on Foreign Direct Investment (FDI) in agricultural production. Figure 2 shows that in 2007–08 when there was a food-price spike, there was also a big increase in FDI in farming. Practically all of that was in low- and middle-income countries. More recent data from UNCTAD indicates that trend has continued. However, FDI in farming remains a small proportion of the total FDI in agricultural value chains, with most investment focused on inputs, processing and marketing (Byerlee & Deininger 2013).

** Savills is a global land management and investment advice company.

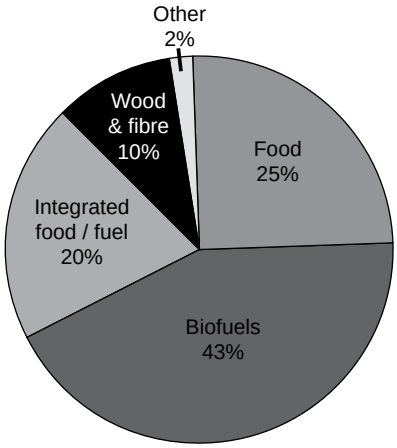


Figure 3. Estimated distribution of large-scale investments across 18 Mha in sub-Saharan Africa, 2005–11 (Schoneveld 2011).

Another way of estimating the investment in land is in terms of the area acquired. Some of the numbers cited for large-scale land acquisitions by investors in various regions of the world seem to be wildly exaggerated. More believable and fairly well verified is the estimate by the Centre for International Forestry Research (CIFOR; Schoneveld 2011). It finds that since 2005 the amount of land acquired in sub-Saharan Africa by investors (that is, land parcels larger than 2000 ha) was 18 Mha. That is comparable to the area quoted by the World Bank, and certainly less than the area that Oxfam (2011) has been mentioning.

The largest allocation in Africa has been for biofuels; the second largest was for food crops (Figure 3), and within food crops rice was most important.

In some countries, actual ownership of land can be estimated from national statistics, such as those collected annually and published for the USA. Something like 10 Mha of land in the US had some foreign ownership in 2011. It was mostly used for timber and pasture. Large-scale investments can become confused with foreign investments in the media, but in the US several domestic sources, such as big pension funds, are large domestic investors. For instance, TIAFF-CREF, probably the biggest pension fund in the world, is investing quite heavily in farmland. On the other hand, a significant number of US states do not allow corporate investment, neither domestic nor foreign, in farmland.

In Australia the Australian Bureau of Statistics has estimated that 44 Mha is under some form of foreign ownership (Moir 2011). About 43 Mha of that is estimated to be in pastoral areas (Byerlee unpublished), and therefore only 1 Mha of it is in crop land.

The investors in farms are a very mixed group of companies and people. State-owned investments, whether through governments or state companies or sovereign wealth funds, are relatively small at the global level. They are important in some countries like Sudan and perhaps Cambodia, but the major investors are in private enterprise. Those investors include specialised

Table 2. Overview of types of investors in farmland in different land market contexts (the more the x the greater the importance).

Type of investor	Type of land market	
	Private land markets	Government-mediated land concessions
State		
Governments	-	x
Sovereign wealth funds	x	x
State-owned companies	x	
Private		
Agribusiness	xxx	xxx
Energy	xx	xx
Portfolio (managed)	xxx	x
Other (timber, speculative)	x	xxx

agribusiness companies and energy companies because of the biofuel connections, and also the portfolio investors. Portfolio investors can manage directly or rent out the land, or invest in the agribusiness and energy companies. Some investors are not interested in farming at all. Instead they are interested in the timber, or in speculation (Table 2).

Generally, investing companies are not the well-known global agribusiness multi-nationals. In Latin America they are mostly regional companies that often have over 100,000 ha of good crop land; the biggest company has up to a million hectares. In South-East Asia, the big companies are palm oil producers and they earn billions of dollars as their annual revenue: eight of the world's largest 25 agricultural production companies grow palm oil. In Africa, there is much FDI from a very heterogeneous group of companies. In Russia and the Ukraine, 40 and 30 'superfarms', again homegrown companies, respectively manage 4.5 Mha and 6.7 Mha in total.

Opportunities and risk

Since the economic reforms of the 1980s and 1990s, foreign investment has generally been regarded favourably by most governments. It has provided needed capital, and led to transfer of technology, creation of new industries, and so on. There are also significant risks, particularly when investing directly in farming, and those risks are particularly high in areas that lack functioning land markets.

Here are some examples of opportunities and risk. First, oil palm. It is an African crop that has moved to South-East Asia where the industry is now booming. The value of palm oil exports from South-East Asia exceeds the value

of *all* agricultural exports from sub-Saharan Africa. Although palm oil was a lost opportunity for sub-Saharan Africa, the South-East Asian companies are now investing, very aggressively, in Africa. There are literally billions of dollars at stake here in terms of investments, and up to 3 Mha of land. Oil palm is a crop that creates numerous jobs (200–300 jobs per 1000 ha) and holds much potential for the involvement of smallholders. Those are desirable characteristics for spreading the benefits. However, companies need to learn the negative lessons from the South-East Asian palm oil expansion in terms of extensive tropical deforestation and land conflicts.

There are also questions about fair deals. Some of these companies are getting land for US $1–5/ha, yet oil palm yields net returns of at least US $2000/ha. That is an example of the unequal negotiating positions in terms of these land concessions.

The Ukraine is an example of a different opportunity. Agriculture there was de-capitalised after the fall of the Soviet Union in 1991, leaving the Ukraine with big needs for investment and for transfer of technology, which have been met to some extent, and have increased jobs and wages (Petrick et al. 2012). The Ukraine has become a significant exporter of grain and oil seed in world markets (Liefert et al. 2009). However, it lacks a private land market, and land rentals are being provided by small landowners at very low rental values. These are people who received their land after the breakup of the collective farms (mostly pensioners and other poor people) and who have low negotiating powers. Land holdings by large companies with over 10,000 ha have grown from less than 2 Mha in around 20 holdings in 2007 to around 5 Mha in approximately 80 holdings in 2011 (Byerlee et al. 2012). There have also been problems because these investments tend to be risky. Morgan Stanley, a large Wall St bank, is one example of a portfolio investor that has withdrawn, having lost money in Ukrainian farming.

Large investments in a weak institutional and regulatory environment often result in high environmental and social costs. In Indonesia, plantations for oil palm and forestry have taken over hundreds of square kilometres of tropical forests, for example.

Social risk is the largest issue in areas without functioning land markets. Land rights are lost, and the food security of local farmers and communities may be undermined. Mozambique is an interesting example here, because this country since 1998 has had land laws that do recognise communities' land rights. Communities can demarcate their rights and register them. Mozambique is also a country where plenty of land is available, with only 4 Mha cropped in 34 Mha of arable land, and there has been a very aggressive program for attracting private investors. However, while one ministry was demarcating community rights another ministry was handing out land to private investors. The result was 1.4 Mha of overlapping rights. The issue here has been implementation of the laws, and the government of Mozambique has recognised that and set a moratorium on land concessions until measures are in place to avoid these types of conflicts in land allocation.

Figure 4. Australia is a leader in free trade and investment in agriculture. Surely it does not need to brand the land?

Many agricultural investments also fail on economic grounds. One example is in Sudan where a very large area of up to 11 Mha has been used for sorghum and sesame cultivation since the 1970s (Government of Sudan 2009). The plan was for Sudan to become a breadbasket for the Gulf states after the 1970s oil price spike and food price spike. The venture has not been a success, even on economic grounds, with sorghum yields averaging only 0.5 t/ha, whereas 4 t/ha could be expected in the same sort of environment in Queensland. Issues encountered in the Sudan have included soil degradation, lack of technology and loss of land rights by the pastoral people who had been using that land (Johnson 2003; Pantuliano 2007).

Risks and opportunities in Australia

In Australia, foreign investment in farmland is not new. Ever since the settlement of Australia the pastoral areas have had foreign investment, especially in the northern areas in cattle properties, but also in crop production. For example, there was the Peak Downs scheme (Rogers 2008) in the 1940s after the Second World War, which was a parallel to the groundnut scheme in Tanzania (Wood 1952) (both failed), and efforts by large investors to produce sorghum in the Northern Territory in the 1960s and 1970s also failed.

There have also been successes, including the often-highlighted example of American investors establishing the cotton industry in New South Wales.

Australia has strong established institutions and regulations, and the risks look quite low. Much of the fear about private investors coming into Australia comes from a lack of transparency: people want to know who is investing where. If authorities made it a priority to improve access to information about investments and investors, that could remove anxiety.

In the US in the 1970s there were similar fears about the influx of foreign investors, after a food price spike at that time. An annual registry was established, on which all foreign investors had to register; it is published every year. Foreign investment in farmland is not an issue there now.

Table 3. Summary of risks of land acquisitions in countries and regions at different stages of market, institutional and regulatory development.

	State of markets	Example	Social risks	Environmental risks
A	Land and other markets and regulatory environment function well	Australia, Argentina, Southern Brazil	Few	Few
B	Land and other markets and regulatory environment emerging	Ukraine, Central Brazil	Some	High on the forest margin
C	Lack of formal land markets and land rights, and poorly developed regulatory environment	Africa, South-East Asia	Substantial	High on the forest margin

Is Australia going to put a brand name on the land (Figure 4), or are we going to put our brand name on our ideals? As an Australian who has been overseas for many years, I have been able to stand up in meetings and say: 'I come from a country that practises what it preaches in free trade. We do not subsidise our farmers. We do not protect agriculture.'

Australia really has a reputation in providing that sort of global leadership in terms of free trade. Free investment goes along with free trade. Let us not undermine that image. The first step should be to set up a registry for foreign investors, as the federal government has now proposed, to provide reliable information to all — farmers, investors, government and the media — to inform the debate.

Policy priorities for investment

In the context of policy priorities it is useful to think of three types of countries (Table 3). In the first group of countries, which includes Australia, the land and other markets work fairly well, and the priority is to improve transparency about the investors.

The second group of countries includes emerging countries such as the Ukraine and Brazil. There the priorities include improving land markets, and defending property rights, and equalising opportunities particularly for family farmers. In the past, these countries' policies have often favoured large companies.

For the third group of countries, which are mostly in sub-Saharan Africa and South-East Asia, a policy priority should be to formalise existing property rights of local communities and farmers, in a fully transparent manner. Before handing out land, ideally their governments should strengthen community capacity to negotiate good deals, and put mechanisms in place to monitor land ownership and rights. Policy priorities should favour the smallholders as the drivers of agricultural growth and poverty reduction.

Many of the current land concessions at $1–5/ha in this third group of countries seem to be essentially subsidies. It is important to even-up conditions and opportunities for all sizes of enterprise.

A series of guidelines are being prepared for investors. The World Bank, the FAO, the International Fund for Agricultural Development (IFAD) and others have set principles for responsible agricultural investment. In recent years, several private-sector roundtables have become influential in certification. These are voluntary groups such as the Roundtable on Responsible Soy, the Roundtable on Sustainable Palm Oil, the Better Sugarcane Initiative, and so on. They have set environmental standards, social standards and standards relating to local land rights, and it seems they are starting to make a difference.

Is there a global land rush?

To answer the title question, yes, there has definitely been a sharp increase in investments in land globally over the last five years or so, although it has not been as substantial as has been reported in the media.

Major driving factors have included land scarcity and the availability of low-cost land in some countries — and also high commodity prices. A fall in commodity prices is likely to quickly dampen these types of investments.

Another factor has been the low returns to investors in non-agricultural enterprises such as equity funds, which has stimulated many of the portfolio investors to turn to farmland.

It is crucial to ensure there is transparency globally, and monitoring of land-ownership and investment. In Africa and South-East Asia, Australian aid could play a large role, to help define and strengthen property rights of local land users. Australia could also work with investors to make their investments more inclusive, such as by underwriting some of those costs of including outgrower schemes as part of these investments.

In Australia itself, there needs to be an investor register and monitoring of ownership. That way, this country can continue to provide leadership to the world in terms of free trade and investment.

NOTE: This paper is based on Byerlee & Deininger 2013 (in press).

References

Alexandratos N. & Bruinsma J. (2012). *World agriculture towards 2030/50. The 2012 revision.* ESA Working Paper no. 12-03. Rome: FAO.

Byerlee D. & Deininger K. (2013). Growing resource scarcity and rising global investment in farmland. *Annual Reviews of Resource Economics* 5 (in press).

Byerlee D., Lissitsa A. & Savanti P. (2012). Corporate models of broadacre crop farming: International experience from Argentina and Ukraine. *Farm Policy Institute Journal* 9(2): 13–25.

Deininger K., Selod H. & Burns A. (2011). *Improving governance of land and associated natural resources: The Land Governance Assessment Framework*. Washington, DC: World Bank.

Fuglie K.O. (2012). Productivity growth and technology capital in the global agricultural economy. In: Fuglie K., Wang S.L. & Ball V.E. (Eds) *Productivity growth in agriculture: An international perspective*. Wallingford, Oxon, UK: CAB International.

Government of Sudan (2009). Study on the sustainable development of semi-mechanized rainfed farming. Khartoum: Ministry of Agriculture and Forestry.

Lambin E.F. & Meyfroidt P. (2011). Global land use change, economic globalization, and the looming land scarcity. *PNAS* 108: 3465–3472.

Johnson D.H. (2003). *The root causes of Sudan's civil war*. Bloomington, IN: Indiana University Press.

Maturana J. (2005). *Economic costs and benefits of allocating forest land for industrial tree plantation development in Indonesia*. Bogor, Indonesia: Center for International Forest Research.

Moir B. (2011). *Foreign investment and Australian agriculture*. Canberra: Rural Industries Research and Development Corporation.

Oxfam (2011). *Land and power: The growing scandal surrounding the new wave of investments in land*. Oxfam Briefing Paper.

Pantuliano S. (2007). *The land question: Sudan's peace nemesis*. Humanitarian Policy Group Working paper. London: Overseas Development Institute.

Petrick M., Wandel J. & Karsten K. (2012). *Rediscovering the virgin lands: Agricultural investment and rural livelihoods in a Eurasian frontier area*. World Development (forthcoming).

Rogers P. (2008). The 'failure' of the Peak Downs Scheme. *Australian Journal of Politics and History* 10(1): 70–82.

Savills (2012). *International farmland focus: Going with the grain*. London: Savills.

Schoneveld G. (2011). *The anatomy of large-scale farmland acquisitions in subsaharan Africa*. Working Paper 85. Bogor, Indonesia: Center for International Forestry Research.

UNCTAD (2009). *World investment report 2009: Transnational corporations, agricultural production, and development*. New York and Geneva: United Nations Conference on Trade and Development.

Wood A. (1952). *The Groundnut Affair* (London: Unwin, 1950).

Dr Derek Byerlee, from Orroroo, South Australia, is currently working with a number of international organisations on foreign investment, corporate agriculture and land use. He was recently co-author of the World Bank report 'Rising Global Interest in Farmland'. Formerly he was Rural Strategy Adviser of the World Bank and Co-Director of the 2008 World Development Report 'Agriculture for Development'. Before joining the World Bank he was Director of Economics at the International Maize and Wheat Improvement Center, Mexico, and Associate Professor, Michigan State University, USA. He has published widely in several fields of agricultural development and is a Fellow of the American Association of Agricultural Economics.

Email: dbyerlee@gmail.com

The slumbering giant: land and water degradation

Dr Andrew Noble
International Water Management Institute (IWMI)

Abstract

Who feeds the world? Two billion small-scale farmers who in addition to feeding themselves also produce surpluses for local markets — these are the food producers for a global population. Domestic markets along with the food consumed by the producers' families constitute more than 70% of the world's food consumption and are often overlooked in the food security debate. The importance of these producers to overall global food security is not in dispute, but can these farming systems continue to perform at current or improved levels, considering the influence of human-induced land and water degradation and associated effects on ecosystem services? Soil erosion, depletion of nutrients and soil organic matter, salinisation and surface and groundwater pollution are challenges that have confronted agricultural and urban communities for decades, and still do. Land degradation associated with inappropriate and unsustainable land use practices is estimated to affect 5–10 Mha annually; 34 Mha of global irrigated areas is affected by salinisation; it is estimated that 25% of global freshwater storage capacity will be lost in the next 25–50 years unless measures are taken to control sedimentation in reservoirs; approximately 2 Mt of waste is dumped into rivers, lakes and wetlands each day; and it is estimated that there are now 12,000 km^3 of polluted water on the planet, a volume greater than the contents of the world's ten biggest river basins. This litany of land and water degradation issues represents a diminished ability of ecosystems or landscapes to support functions and services required to sustain livelihoods. Small-scale farmers, the engine of global food supply, are the mainstay of most developing country rural economies and often occupy marginal and vulnerable lands. It makes sound economic sense to address this 'slumbering giant' of degradation through increased conservation investments in land and water resources within this sector. Whilst technologies, technology packages and management practices have been developed that demonstrate the practicalities of addressing these resource degradation issues, adoption at scale has been disappointing. Government institutions and development and research organisations are tasked with sustainably securing future food supplies. Their central challenge is to develop greater insights into constraints inhibiting adoption of productivity-enhancing and conserving interventions, and to identify the driving factors and relevant levers to address these constraints. Time may not be on our side in addressing land and water degradation, central to one of the nine thresholds that define 'a safe operating space for humanity'.

In this year, the Australian Year of the Farmer, we celebrate the contributions these custodians and stewards of a significant proportion of the nation's land and water resources have made to putting food on the tables of Australians and others far from these shores. These farmers, with other predominantly small-scale farmers, have over the past 50 years kept pace with global food demand and helped decrease the proportion of the world's people that go hungry, despite a doubling of the total global population. This is an outstanding achievement by any measure.

The growth in food production has largely been achieved by 2 billion small-scale farmers, who in addition to feeding themselves, produce surpluses for sale into local domestic markets. Those domestic markets and the food consumed by the producers' families, which together constitute more than 70% of the world's food consumption, are often overlooked in the food security debate. These producers are the current engine of global food production and the importance of them and their production systems to overall global food security is not in question.

Do these systems have the capacity to continue to perform at current levels, as well as increasing output to meet future demand?

Yield stagnation, and in some cases decline, in several of our grain production systems is a concern for those charged with ensuring future global food requirements. Human-induced land and water degradation and associated provisioning of ecosystem services threaten the integrity of both small and large farming systems and their capability to meet future food demands. Soil erosion, depletion of nutrients and soil organic matter, desertification, salinisation, salt water intrusion, surface and groundwater pollution, groundwater depletion, urbanisation and encroachment and wetland degradation are all challenges that have confronted agricultural and urban communities for decades. Yet resolution of these issues continues to elude us.

The title of this paper describes the issue of land and water degradation as a 'slumbering giant'. The term reflects the significance of the problem. Challenges associated with reversing the degradation are enormous, and though they receive little space on the global agenda they have considerable implications for future food supply. Our goal as a global community should be to address these issues head-on and ensure that the slumbering giant does not awaken.

Human induced degradation and food production systems

There is general agreement that the global population will continue to grow until it possibly plateaus at 9 billion people by roughly the middle of this century. The deceleration in population growth is predicated on increased wealth. With more purchasing power comes increased consumption and a greater demand for processed food, meat, dairy and fish, all of which add pressure to the supply system (Godfray et al. 2010). Associated with these changes, food producers are experiencing greater competition for land, water and energy, and the need to curb the many negative externalities of food production systems on the environment (Tilman et al. 2001; Millennium Ecosystem Assessment

2005). There is also the overarching threat of climate change and its potential implications for food systems and the resources they depend on.

Recent discourse has broadened the definition of 'land degradation' beyond the traditional notion of soil erosion and water pollution and loss in soil fertility. It now also encompasses the deterioration of a balanced ecosystem and the loss of services that ecosystems provide (Nachtergaele et al. 2011). The new definition captures a more inclusive and integrated view of resources. It identifies that provision of goods and services by ecosystems is critical to the functionality and sustainability of these systems. More importantly this wider definition captures the biophysical and socio-economic dimensions of degradation, the latter being a key to addressing the problem.

The global community currently faces challenges that include the global financial crisis, extreme climatic events attributed in part to climate change, and the shift in geopolitical power from west to east. As well, the Earth's systems have moved from a period of environmental stability, characterised in geologic terms as the Holocene, to a new era, the Anthropocene, in which human actions have become the main driving factor in global environmental change (Crutzen 2002; Steffen et al. 2007). The consequences could irreversibly and, in some cases, abruptly lead to a state less conducive to human development (Steffen et al. 2004). Indeed recent evidence suggests that humans have exceeded three of nine so-called 'planetary boundaries': climate change, rate of biodiversity loss and the nitrogen cycle, all of which have strong linkages to the agricultural sector (Rockström et al. 2009).

The success of the agrarian sector in providing food, feed and fibre to an ever increasing global population has been based on use of nitrogenous fertilisers and nitrogen-fixing legume species. These have perturbed the global nitrogen cycle by generating reactive nitrogen, and have contributed to greenhouse gas emissions. A dependence on fossil fuels together with widespread changes in land use have contributed to increasing greenhouse gases in our atmosphere, loss of biodiversity and extinction of species. As a sector, agricultural production has made a significant contribution to the overstepping of these three planetary boundaries.

The litany of issues that confront us with respect to land and water degradation globally is well documented. It portrays a dismal assessment of the impacts of human-induced land use change for agriculture. Globally, approximately 25% of all land is classified as highly degraded, with a mere 10% being classified as improving in condition (FAO 2011). On an annual basis, inappropriate and unsustainable land use practices are estimated to affect 5–10 Mha annually out of a total of 1600 Mha (1.6 billion ha) that are currently in crop production (Scherr & Yadav 1996). Of 1094 Mha affected by water erosion, 751 Mha are severely affected. Of 549 Mha of land suffering from wind erosion, 296 Mha are severely affected (Oldeman 1994; Lal 2003). The salinisation affecting 34 Mha of the global irrigated area represents a significant lost opportunity and under-utilisation of investment in infrastructure. It is estimated that 25% of global freshwater storage capacity will be lost in the next 25–50 years unless measures are taken to control sedimentation in reservoirs. Approximately 2 Mt of waste is dumped

into rivers, lakes and wetlands each day, causing eutrophication and hypoxia and algal blooms; and it is estimated that there are now 12,000 km^3 of polluted water on the planet — a volume greater than the contents of the world's ten biggest river basins (FAO 2011). These points are not exhaustive; they represent the major challenges that we face in land and water degradation as we move into an era where stability in the Earth's systems will be the exception rather than the rule.

In short, the land and water degradation issues that confront us all diminish the capacity of vital ecosystems and landscapes to support functions and services required to sustain mankind. For brevity, only some aspects of land and water degradation are highlighted and discussed below.

Impacts of agricultural systems

Agricultural systems are part of both the problem and the solution to global climate change. Consider these systems' contributions to global greenhouse gas emissions that have forcing effects on climate.

On an annual basis, emissions from agriculture contribute 5000–6000 Mt CO_2-e (carbon dioxide equivalent). Together with deforestration — often associated with food production systems — agriculture is responsible for a third of total human-induced greenhouse gas emissions, or about 13,000–15,000 Mt CO_2-e per year (FAO 2011).

Various parts of the agricultural sector contribute different forms and amounts of greenhouse gases:

- agriculture and associated deforestation contribute to 25% of the total global greenhouse gas emissions;
- of total global methane emissions, 50% are derived from rice-based systems, enteric fermentation and generation of animal wastes; and
- of global N_2O emissions, 75% are generated from fertilisers and animal waste.

These proportions show where efforts should be focused to reduce the sector's overall emissions footprint.

In intensified production systems, which will be important in meeting future food demand, many of these emissions are unavoidable. However, there are mitigation strategies in both the agricultural and forestry sectors that will be critical in stabilising atmospheric concentrations. The Carbon Farming Initiative, part of the Australian Government's Clean Energy Future Program, reflects the role that agriculture will play in being part of the solution to addressing greenhouse gas emissions.

Salinisation of land has threatened civilisations in ancient and modern times. Southern Mesopotamia and parts of the Tigris–Euphrates river basins that for centuries supported thriving ancient societies were destroyed by salinity (Jacobsen & Adams 1958; Hillel 2005). A repeat of the saga is currently being played out in the Mesopotamia Plains of Iraq, the Indus basin and the Amudarya and Sydarya basins of central Asia, clearly demonstrating that we have not learnt from history.

In 2006, globally, irrigated agriculture was equipped to deliver water to 301 Mha; 70% of this production capacity was in Asia (FAO 2011). Globally 34 Mha are now affected by salinity, representing 11% of the total irrigated area. The largest areas affected are in Pakistan, China and the United States (FAO 2011). It is estimated that 1.5 Mha of arable land are lost annually because of salinity, along with an estimated $11 billion in lost production (Wood et al. 2000).

The total area of salt-affected soils, which includes both saline and sodic soils, is estimated to be 831 Mha (Martinez-Beltran & Manzur 2005). In Australia in 2001, the National Land and Water Resources Audit (NLWRA 2001) estimated that approximately 5.7 Mha of agricultural and pastoral lands had a high potential for developing salinity through shallow water tables, and that this figure could grow to 17 Mha by 2050.

The development of salinity is based on soil and groundwater processes that interact with our ways of managing landscapes and irrigated areas. Natural salinisation of land and water is closely related to the long-term accumulation of salts in the soil profile and subsequently in the groundwater. Poor water management, and inappropriate drainage and management of saline drainage discharge all contribute to the salinisation of irrigated lands.

Globally only half the nutrients that crops take from the soil are replaced (Comprehensive Assessment of Water Management in Agriculture 2007). Depletion of soil nutrients often leads to fertility levels that limit production and severely reduce water productivity. This issue of soil nutrient mining is a fundamental problem in Africa, leading to yield stagnation and in many cases decline. It has been estimated that 85% (185 Mha) of African farmland had nutrient mining rates of more than 30 kg/ha annually during 2002–04, and 40% had rates greater than 60 kg/ha annually (Table 1) (Henao & Baanante 2006). Approximately 95 Mha of soils had reached a state of degradation in which large investments would be required to bring them back to a productive level. Nutrient depletion was high (>60 kg NPK/ha annually) in agricultural lands of Guinea, Congo, Angola, Rwanda, Burundi and Uganda (Table 1); little fertiliser is used in these countries and the high nutrient losses are linked to soil erosion and leaching. Contrasting this, in the North Africa region and South Africa, although constrained by poorer climatic attributes, rates of nutrient depletion are smaller, varying from 0 to 30 kg NPK/ha annually.

Total nutrient depletion in sub-Saharan Africa on an annual basis has been estimated at around 8 Mt NPK (Henao & Baanante 2006). Nitrogen and phosphorus are lost when soils are eroded by wind and/or water, and nitrogen and potassium are lost via leaching. If erosion continues unabated, yields could be 17–30% lower by 2020, amounting to around 10 Mt of cereals, 15 Mt of roots and tubers and 1 Mt of pulses (Henao & Baanante 2006).

The overall economic impact of land degradation in Africa, of which nutrient mining is a significant component, has been estimated from imports of grain (Henao & Baanante 2006). According to FAO statistics, Africa imported about 43 Mt of cereals at a total cost of US $7.5 billion during 2003 (FAO 2004). Assuming that current agricultural land management practices will not change dramatically until 2020 and assuming that the population of Africa will continue

Table 1. Average annual losses of nitrogen, phosphorus and potassium during 2002–04 in countries in sub-Saharan Africa (based on Henao & Baanante 2006).

Moderate–low (<30 kg/ha)		**Medium (30–60 kg/ha)**		**High (>60 kg/ha)**	
	kg/ha		kg/ha		kg/ha
Egypt	9	Libya	33	Tanzania	61
Mauritius	15	Swaziland	37	Mauritania	63
South Africa	23	Senegal	41	Congo Republic	64
Zambia	25	Tunisia	42	Guinea	64
Morocco	27	Burkina Faso	43	Lesotho	65
Algeria	28	Benin	44	Madagascar	65
		Cameroon	44	Liberia	66
		Sierra Leone	46	Uganda	66
		Botswana	47	Congo Democratic Republic	68
		Sudan	47	Kenya	69
		Togo	47	Central African Republic	69
		Côte d'Ivoire	48	Gabon	69
		Ethiopia	49	Angola	70
		Mali	49	Gambia	71
		Djibouti	50	Malawi	72
		Mozambique	51	Guinea Bissau	73
		Zimbabwe	53	Namibia	73
		Niger	56	Burundi	77
		Chad	57	Rwanda	77
		Nigeria	57	Equatorial Guinea	83
		Eritrea	58	Somalia	88
		Ghana	58		

to increase, it is projected that Africa will be importing about 60 Mt of cereals, which could cost about US $14 billion. Such levels of imports will have a significant impact on the economies of countries and pose challenges with respect to food security.

The combined effects of a stagnating agricultural sector, high rates of soil erosion, deforestation and desertification are trapping African agriculture in a downward spiral. These symptoms appear throughout African farming regions and are in part the consequences of nutrient depletion and high population pressure all contributing to resource degradation.

As population growth in most of the agricultural regions of Africa continues to increase the demand for food and services, these ecosystems will no longer be able support the livelihoods of communities, resulting in out-migration to other

areas or, more commonly, to urban centres. If current nutrient mining rates and degradation of land continue, it has been argued that it is very difficult to foresee how farmers in African countries will have enough productive soil to grow adequate food and feed for populous urban centres and the rural areas of Africa during the next century (Henao & Baanante 2006).

This is possibly an overly pessimistic view of the consequences of continued land and water resource degradation, but it highlights the critical point that has been reached in Africa. There is a need for a transformative approach to addressing these issues.

Although land use practices vary greatly across the globe, their ultimate outcome is generally the same: the acquisition of natural resources for immediate human needs, often with risk of degrading the condition of the environment. Expansion and intensification of agricultural production systems have contributed to loss of biodiversity within landscapes. Modification and fragmentation of habitats associated with land use change, erosion, overgrazing and the silting up of wetlands have contributed to large shifts in biodiversity. Intensification of agriculture, often accompanied by farm and field consolidation, reduction of field margins, clearing and levelling of adjacent water catchments (watersheds), wider use of modern varieties, heavy use of fertilisers, pesticides and agrochemicals all contribute to degradation of water systems, eutrophication and a decrease in aquatic biodiversity (Foley et al. 2005). The insatiable appropriation of an ever-larger fraction of the biosphere's goods and services has resulted in the highest rate of biodiversity loss since the last global mass-extinction event, and has pushed us over this planetary boundary (Rockström et al. 2009).

In 2009, the number of chronically malnourished persons reached an all-time high, exceeding 1 billion (IFAD 2010). In the same year, the World Food Programme delivered food assistance to over 101.8 million people suffering from an acute shortage of food (WFP 2010). Recent food crises have incited political unrest and spurred large-scale agricultural investment in the tropics, often displacing local people and critical ecosystems (Deininger & Byerlee 2011).

While there is no evidence to suggest that land and water degradation contributed to the recent global food crisis there are contrasting views over the impact that resource degradation has on productivity. Wiebe (2003) claimed that land degradation at a global scale causes annual productivity declines in the order of only 0.4% for the major crops, and that the real impact on food production is masked through technological advances and inputs — driving factors that will have less of an influence in the future. However, other studies suggest that land degradation can threaten the food security of poor people in fragile environments, particularly those whose livelihoods rely largely on agricultural activities (Scherr 1999; Sanchez 2002). A study undertaken in Tanzania found that although the average percentage of rural household income derived from agriculture was almost 50%, this figure rose to almost 70% for the poorest income quartile (Ellis & Mdoe 2003). These findings emphasise the relatively high sensitivity of the poor to resource degradation.

The impact of degradation associated with inappropriate land and water management on potential yield loss can be estimated from the yield foregone

because of land retirement in irrigated areas due to salinity. Assuming that the 34 Mha currently affected by salinity were brought back into production to yield a conservative annual production potential of 4 t/ha grain, the potential production generated is 136 Mt of grain annually which is approximately 20% of the global wheat yield of 2010–11 (USDA 2012). Bringing these salinised irrigated areas back into production could make a significant contribution to global food security without expanding the production area — with associated challenges.

Addressing land and water resource degradation makes sound economic sense. These are production variables that, in theory, a farmer can control — in contrast to climate change and climate variability, market forces and political change. However, controlling land and water degradation will take considerable support and political will, because the problem is one of those eloquently labelled 'wicked'.

Addressing land and water degradation

The problem of land degradation was described as a 'wicked problem' by the Australian Public Service Commission (APSC 2007). It stated (p. 2):

> *Land degradation is a serious national problem. Given that around 60% of Australia's land is managed by private landholders, it is clear that assisting and motivating primary producers to adopt sustainable production systems is central to preventing further degradation, achieving rehabilitation and assisting in sustainable resource use. All levels of government are involved in land use as is a range of NGOs.*

One might add that, at global scale, mobilising 2 billion smallholder private farmers to adopt sustainable production systems is in itself a monumental challenge, although there are examples of success in addressing resource degradation amongst these producers.

It is important to understand why land degradation has been described as a wicked problem. The label places the issue in a distinct category of problem sets that cannot be solved relatively simply.

Wicked problems commonly have the following attributes: they are difficult to define; have many interdependencies and are often multi-causal; often lead to unforeseen consequences when addressed; are often unstable; usually have no clear solution; are socially complex; and often involve changing behaviour. Climate change and obesity are similarly classified as wicked problems (APSC 2007) and one could argue that the challenges in managing Australia's Murray-Darling Basin would also fall into this category, which clearly highlights the complexity and possibly intractable nature of the issue.

Although the term 'wicked' conjures up a sense of hopelessness or despair in resolving the problem, I am of the opinion that we as a community should see the issues as a challenge that will require science, policy and politics to address. We should not accept that because it is a wicked problem there is no solution. Globally there is a cadre of bright and talented young people who should be encouraged to take on these issues that have scientific, policy and political dimensions, through innovation.

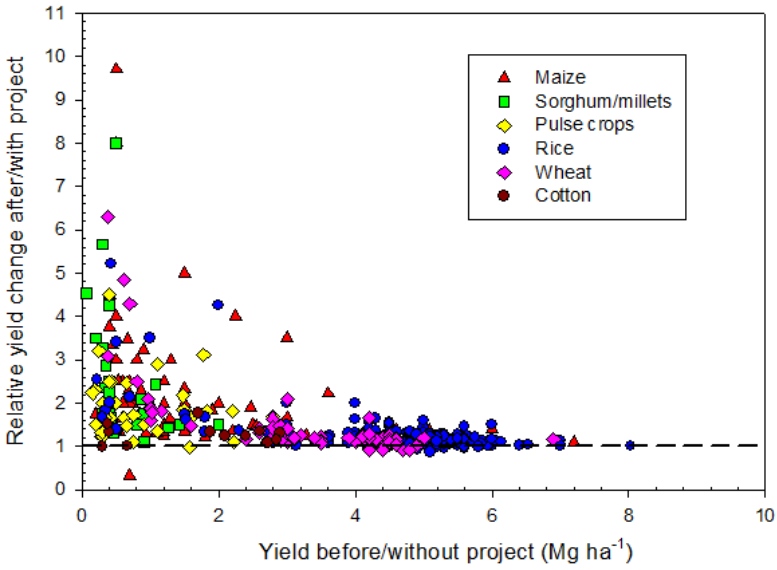


Figure 1. Changes in the yields of agronomic crops with the adoption of new technologies and practices globally (Noble et al. 2006). The data set is made up of 446 crop yields from 286 projects. Dashed line indicates no change in relative yield.

The picture may look bleak with respect to land degradation but there is cause for cautious optimism that the tide may be slowly turning. In a study reported in 2006, 286 recent interventions in 57 poor countries covering 37 Mha (3% of the cultivated area in developing countries) have increased productivity on 12.6 million farms while improving the supply of critical environmental services. The average crop yield increase was 79% with the largest increases being observed in rainfed systems (Figure 1; Noble et al. 2006). All crops showed water use efficiency gains, and the highest improvement was in rainfed crops. Potential carbon sequestered amounted to an average of 0.35 t C/ha/year. If a quarter of the total area under these farming systems adopted sustainability enhancing practices, it was estimated that global sequestration could be 0.1 Gt C/year. Of projects with pesticide data, 77% resulted in a 71% decline in pesticide use while yields grew by 42% (Pretty et al. 2006).

An analysis of 40 projects and programs in 20 countries in Africa where sustainable intensification had been developed during the 1990s–2000s has revealed some interesting insights into the impact of these interventions (Pretty et al. 2012). By early 2010, these projects had documented benefits for 10.39 million farmers and their families and improvements on approximately 12.75 Mha. Effects on food outputs by sustainable intensification have been multiplicative — in other words, yields per hectare have increased by combining the use of new and improved varieties and new agronomic–agroecological management (crop yields rose on average by 2.13-fold). They have also been additive: diversification has resulted in the emergence of a range of new crops, livestock or fish that added to the staples or vegetables already being cultivated.

The aforementioned are impressive outcomes that demonstrate that promoting sustainable intensification for smallholder farming systems can have tangible results in the form of increased food security and/or incomes while enhancing the functionality of farming systems. However, the challenge we face is a scaling-up of these successes.

The Government of India is attempting to achieve this through multidimensional policy instruments that are linked to poverty alleviation and environmental sustainability objectives. That involves locally appropriate, bottom-up planning. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), launched in 2006, now operates in every district in India. In 2010–11, MGNREGA provided jobs for more than 50 million rural households at a cost of US $9.1 billion. MGNREGA entitles every adult to 100 days a year of minimum wage, unskilled manual employment on public works, such as water management, drought proofing, tree planting, land development and rural connectivity. Over 80% of the projects have contributed to rejuvenating the natural resource base in some way. MGNREGA jobs deliver local environmental services, such as recharging groundwater, enhancing soil fertility and increasing biomass which in turn contribute to climate change resilience and mitigation, as well as conserving biodiversity (Mahapatra 2010). An important part of this initiative is that the MGNREGA recognises the important role of gender in rural areas by specifying that at least one-third of workers should be women.

The recently published report by the Commission on Sustainable Agriculture and Climate Change (Beddington et al. 2012) provides a comprehensive assessment of the challenges and solutions to food security within the context of climate change, encapsulating sustainable and efficient use of natural resources. It makes a comprehensive set of recommendations for policy makers, which would contribute to ensuring that humanity stays within the planetary boundaries. However, the rate of change and transitions that are occurring challenge humans' ability to manage this complexity.

These transitions include, but are not limited to:

- the urban transition where a greater proportion of the global population is living in cities;
- the nutrition transition that has led to changes in dietary habits and greater consumption of processed foods and meat products;
- the climate transition where increases in global temperatures are influencing the water cycle;
- the agricultural transition that is being forced upon us because of the huge increases in food demands in the face of reduced resources; and
- the energy transition from inexpensive fossil fuels to renewable energy resources (Rogers 2012).

All of these are happening simultaneously at differing rates that will require flexibility in the way we manage these changes.

The agricultural transition that is core to our sphere of interest will be influenced to a lesser or greater extent by the other transitions mentioned

and will dramatically change the face of agriculture particularly in developing and emerging countries. For example, in sub-Saharan Africa where there is considerable potential to expand and intensify agricultural production systems, there is the notion that this can be achieved through small-scale farmers (the current mainstay of the food production system) by improvements in technology and its transfer, and functioning markets. This may be a somewhat myopic view of agricultural transformation in sub-Saharan Africa, particularly if one assumes that the region will inevitably follow the same development trajectories that have occurred in North America, Europe, Australia and Brazil. Similar trajectories are currently occurring in South-East and East Asia where de-population of rural areas has resulted in land consolidation, mechanisation and the development of commercial farming systems. Further, it is argued that this transformation of agriculture in sub-Saharan Africa will be influenced by the impacts of climate change.

A move towards large-scale commercial farming systems offers opportunities for addressing land and water resource degradation through improved technology transfer and the enforcement of conservation measures. This is not to say that 'large' is better than 'small' but rather that there needs to be more flexibility in the way agriculture is transformed in developing and emerging countries, and that sovereign governments actively need to play a leading role in facilitating this transformation.

In summary, it makes sound economic sense to address this slumbering giant of degradation through increased conservation investments in land and water resources within this sector. Technologies, technology packages and management practices have been developed which demonstrate the practicalities of addressing these resource degradation issues, but the scale of their adoption has been disappointing. The central challenge facing government institutions, and development and research organisations tasked with sustainably securing future food supplies, is to develop greater insights into the constraints inhibiting adoption of productivity-enhancing and conserving interventions; and to identify the driving factors and relevant levers to address these constraints.

References

APSC (2007). *Tackling Wicked Problems: A Public Policy Perspective. Contemporary Government Challenges*. Australian Public Service Commission, Australian Government, Canberra. http://www.apsc.gov.au/publications-and-media/archive/publications-archive/tackling-wicked-problems

Beddington J., Asaduzzaman M., Clark M., Fernandez A., Guillou M., Jahn M., Erda L., Mamo T., Van Bo N., Nobre C.A., Scholes R., Sharma R. & Wakhungu J. (2012). *Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission

Comprehensive Assessment of Water Management in Agriculture (2007). *Water for Food, Water for Life. Comprehensive Assessment of Water Management in Agriculture*. Molden D. (Ed.) London: Earthscan, and Colombo: International Water Management Institute.

Crutzen P.J. (2002). Geology of mankind: the anthropocene. *Nature* 415: 23.

Deininger K. & Byerlee D. (2011). *Rising global interest in farmland: can it yield sustainable equitable benefits?* Washington, DC: World Bank.

Ellis F. & Mdoe N. (2003). Livelihoods and rural poverty reduction in Tanzania. *World Development* 31: 1367–1384.

FAO (2004). FAO Statistics FAOSTAT, www.faostat.fao.org. FAO, Rome.

FAO (2011). *The state of the world's land and water resources for food and agriculture (SOLAW) — Managing systems at risk*. Food and Agriculture Organization of the United Nations, Rome, and Earthscan, London.

Foley J.A., DeFries R., Asner G.P., Barford C., Bonan G., Carpenter S.R., Chapin F.S., Coe M.T., Daily G.C., Gibbs H.K., Helkowski J.H., Holloway T., Howard E.A., Kucharik C.J., Monfreda C., Patz J.A., Prentice I.C., Ramankutty N. & Snyder P.K. (2005). Global consequences of land use. *Science* 309: 570–574.

Godfray H.C.J., Beddington J.R., Crute I.R., Haddad L., Lawrence D., Muir J.F., Pretty J., Robinson S., Thomas S.M. & Toulmin C. (2010). Food security: The challenge of feeding 9 billion people. *Science* 327: 812–818.

Henao J. & Baanante C. (2006). *Agricultural production and soil nutrient mining in Africa. Implications for resource conservation and policy development*. International Center for Soil Fertility and Agricultural Development, Muscle Shoals, USA.

Hillel D. (2005). Soil salinity: Historical and contemporary perspectives. *Proceedings of the International Salinity Forum*, Riverside, California, April 2005, 235–240.

IFAD (2010). Rural poverty report 2011. *New realities, new challenges: new opportunities for tomorrow's generation*. Rome: International Fund for Agricultural Development.

Jacobsen T. & Adams R.M. (1958). Salt and silt in ancient Mesopotamian agriculture. *Science* 128: 1252.

Lal R. (2003). Soil erosion and the global carbon budget. *Environment International* 29: 437–450.

Mahapatra R. (2010). MGNREGA: Making way for women's empowerment. http://southasia.oneworld.net/fromthegrassroots/mgnrega-paving-way-for-womenempowerment

Martinez-Beltran J. & Manzur C.L. (2005). Overview of salinity problems in the world and FAO strategies to address the problem. *Proceedings of the International Salinity Forum*, Riverside, California, April 2005, 311–313.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being*. Washington, DC: World Resource Institute.

Nachtergaele F.O., Petri. M. & Biancalani R. (2011). Land degradation. Chapter 3 in Lal R. & Stewart B.A. (Eds) *World Soil Resources and Food Security*. Advances in Soil Science. Boca Raton: CRC Press.

NLWRA (2001). *Australian dryland salinity assessment 2000*. Commonwealth of Australia, Canberra: National Land and Water Resources Audit.

Noble A.D., Bossio D.A., Penning de Vries F.W.T., Pretty J. & Thiyagarajan T.M. (2006). *Intensifying agricultural sustainability: An analysis of impacts and drivers in the development of 'bright spots'*. Comprehensive Assessment Research Report 13. Colombo, Sri Lanka: Comprehensive Assessment Secretariat. 42 pages.

Oldeman L. (1994). The global extent of soil degradation. In: Greenland D. & Szabolcs I. (Eds) *Soil Resilience and Sustainable Land Use*. Wallingford, UK, pp. 99–118.

Pretty J., Noble A.D., Bossio D., Dixon J., Hine R.E., Penning de Vries F.W.T. & Morison J.I.L. (2006). Resource-conserving agriculture increases yields in developing countries. *Environmental Science and Technology* 40: 1114–19.

Pretty J., Toulmin C. & Williams S. (2012). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability* 9: 5–24.

Rockström J., Steffen W., Noone K., Persson Å., Chapin III F.S., Lambin E.F., Lenton T.M., Scheffer M., Folke C., Schellnhuber H.J., Nykvist B., de Wit C.A., Hughes T., van der Leeuw S., Rodhe H., Sörlin S., Snyder P.K., Costanza R., Svedin U., Falkenmark M., Karlberg L., Corell R.W., Fabry V.J., Hansen J., Walker B., Liverman D., Richardson K., Crutzen P. & Foley J.A. (2009). A safe operating space for humanity. *Nature* 461: 472–475.

Rogers P. (2012). Looming food and water crisis in Asia. Eye on Asia. World Water Week, Stockholm, Sweden, 28th August 2012.

Sanchez P.A. (2002). Soil fertility and hunger in Africa. *Science* 295: 2019–2020.

Scherr S.J. (1999). *Soil degradation: a threat to developing-country food security by 2020?* Food, Agriculture and the Environment Discussion Paper 27. Washington DC: International Food Policy Research Institute.

Scherr S.J. & Yadav S. (1996). *Land degradation in the developing world: Implications for food, agriculture and environment to 2020*. Food, Agriculture and the Environment Discussion Paper 14. Washington DC: International Food Policy Research Institute.

Steffen W., Sanderson A., Tyson P.D., Jager J., Matson P.A., Moore B., Oldfield F., Richardson K., Schellnhuber H.J., Turner B.L. & Wasson R.J. (2004). *Global Change and the Earth System: A planet under pressure*. The IGBP Series, Springer, Berlin.

Steffen W., Crutzen P.J. & McNeill J.R. (2007). The Anthropocene: Are humans now overwhelming the great forces of Nature? *Ambio* 36: 614–621.

Tilman D., Fargione J., Wolff B., D'Antonio C., Dobson A., Howarth R., Schindler D., Schlesinger W.H., Simberloff D. & Swackhamer D. (2001). Forecasting agriculturally driven global environmental change. *Science* 292: 281–284.

USDA (2012). *Grain: World markets and trade*. United States Department of Agriculture, Circular Series FG 09-12.

Wiebe K. (2003). *Linking land quality, agricultural productivity and food security*. Agricultural Economic Report No. 83. Washington DC: USDA.

WFP (2010). *Fighting hunger worldwide*. Annual report 2010. Rome: World Food Programme.

Wood S., Sebastian K. & Scherr S.J. (2000). Pilot Analysis of Global Ecosystems: Agroecosystems. Washington DC: International Food Policy Research Institute & World Resources Institute.

Prior to being appointed as a Senior Fellow with the International Water Management Institute (IWMI) based in Colombo, Sri Lanka, Dr Andrew Noble was the Research Programme Manager for the Land and Water Resources program in the Australian Centre for International Agricultural Research (ACIAR) and formerly Regional Director for IWMI for South-East and Central Asia; a Principal Research Scientist with CSIRO Land and Water; Project Leader and Principal Research Scientist with the Institute for Commercial Forestry Research; and lecturer in the department of Crop Science, University of KwaZulu Natal South Africa. His research career in agriculture spans more than 30 years and includes research and academic assignments in South Africa, Australia and South-East and Central Asia.

Email: A.noble@cgiar.org

Impacts of mining on land and water resources

Professor Chris Moran
Sustainable Minerals Institute, The University of Queensland

Abstract

Mining of energy resources and minerals is clearly the running down of a large but finite, and non-renewable, resource. It is important also to recognise the non-renewable aspects of food production: in particular, net consumption of nutrients and soil as well as the direct and embodied (manufactured capital, for example) energy sources required to convert the soil and water into food (and fibre). The notion that land is being consumed by mining and not by food and fibre production is inaccurate and largely unhelpful if one is to take a whole system view of resource utilisation. Further, the apparent moral high ground of resource utilisation for food as opposed to mining is also questionable. The relative importance of food over shelter and warmth is not clear even at the inner levels of Maslow's hierarchy of needs. This paper gives an overview of demand for energy and minerals, and of potential to supply, to give context for the Australian situation. Some data are presented to examine the hypothesis that Australia's contribution to global development is jeopardised by resource utilisation for supplying energy and minerals as opposed to food (and fibre). The paper concludes by proposing that the current battle between mining and agriculture in Australia includes a significant emotional component. This is based on the romantic vision of ploughed and green fields tenderly stewarded by salt-of-the-earth folk, in contrast to images of earth rent asunder by the ravages of mining under the assault of savages.

Thank you for introducing this topic and giving this conference the opportunity to discuss another major resource user in the landscape. As the abstract shows, I hold the view that people look at these two resource uses, mining and agriculture, through completely different lenses. This paper's overall message is that I think we should unify the way that we look at *all* resource-using activities. We should begin to look for the synergies that can come to people and environments, and start to pull down the 'walls' that we are building at a very fast and, in my view, unnecessary rate.

I will commence by stating that I think sustainable development is fundamentally about (i) intergenerational equity and (ii) meeting multiple needs. On the first point, as a map of country by country GDP would illustrate, it is clear that we do not have equity in the *current* generation.

On the second point, about meeting multiple needs, I would like to refer to the seminal work on this which is Maslow's hierarchy of needs (Figure 1). The important thing to note here is that food is at the same level of needs as many of

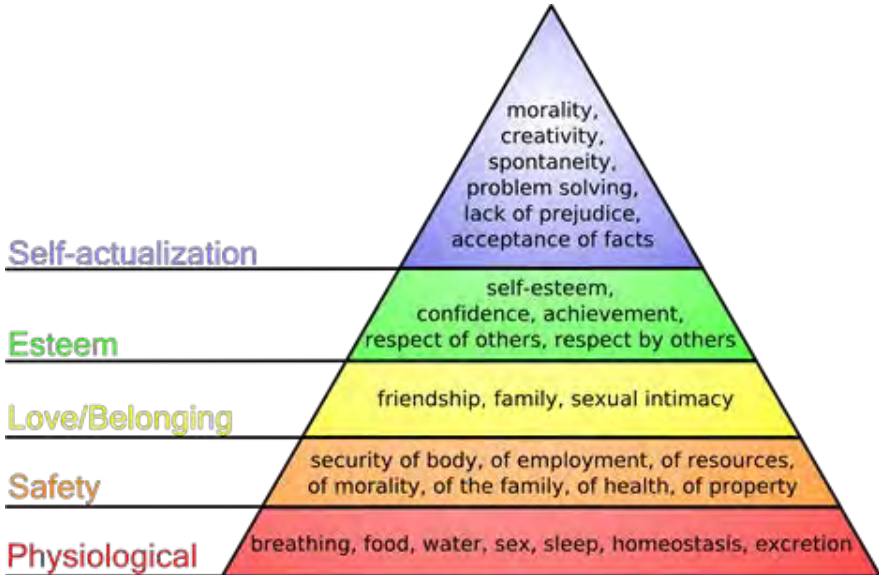


Figure 1. Maslow's hierarchy of needs (Maslow 1954).

the things attained by supplying energy and minerals; that is, warmth, shelter and the ability to consume hygienic food and water.

In 2007 there were 1.3 billion people living without electricity and 900 million without sufficient warmth or food. Is it a helpful trade-off to say it is good to have your stomach full but be cold and in the rain? Instead of a trade-off approach to the challenge, we should be asking: 'Where are there synergies, and what are the true issues here that we need to tackle?'.

In putting together this paper, I started with the view that I would be able to find data to illustrate the competition between mining and food production. To my surprise I was unable to find strong evidence for this being the national-scale issue that the media and some others are depicting. I assert that if we continue with the line that competition is the main problem then we will, within two decades, be dealing with far greater 'wicked' problems than if we make an attempt at integrated resource use and management today.

Wicked problems are characterised by non-linear relationships between issues, feedbacks and uncertainty. They do not have solutions, they only have better (or worse) navigation pathways.

Having removed the *a priori* assertion that food production must be given priority over minerals and energy access, I now pose a number of focusing questions to analyse the depth of the resource competition 'problem' in Australia:

- What is the picture of the relative economic importance of mining and agriculture?

- What are the significant contributions of Australia?
- Where are the overlapping resource competition areas in Australia with respect to food production and mineral and energy access?

Some time ago Rio Tinto, a major mining company, predicted a future that links global development and the demand for energy and minerals. It is well accepted that in the coming two or three decades there will be tremendous global growth, and approximately half of that will be from China and India combined. What Rio Tinto added to these well known projections is a picture of metal intensity per capita for the various metals needed for development: copper, aluminium and iron ore, plus coking coal for steel. Over the GDP levels that the coming growth will achieve we pass through the maximum rate of increase in required metal intensity. This translates into a massive forward decadal-scale demand.

The other side of that is the energy that is required to convert the raw materials into infrastructure that supports development. This demand for metals and energy is coming in exactly the same time period as the projected global food crisis. It is a perfect recipe for rapid development of a wicked problem — that is, if we look at supply from a competitive, rather than a synergistic, perspective.

Now let us look at how energy has been supplied, and the likely future sources. In the last decade we have met most of the increased demand for energy globally from coal, then gas. Renewable energy supplies have increased at about the same rate as gas but at a much lower magnitude. For us to meet the energy demand for development from renewables would require the trajectory to become even steeper than the rapid increase in Chinese energy imports since the year 2000[1] — a very tall order indeed. The alternative is simply to slow down development, which is a moral dilemma of gargantuan proportions: people on one side of the planet deciding that local resource competition for relatively small quantities of water, for example, should drive decision making to constrain the capacity of millions of people to lift themselves out of poverty!

If we look at the supply of minerals we find that there is great prospectivity around the world, and mostly in regions where mining is already prevalent or in new geopolitically-challenging areas such as the Democratic Republic of Congo and Papua New Guinea. Will all this mining turn the world into one massive mine pit? Well, of course not.

There are significant impacts of mining. There are significant environmental impacts of mining; there are significant social impacts of mining. I am certainly not saying that these are not important, or that we should not map them, or that we should not look at them and manage them with the other resource-using activities. However, instead of pointing out all the unpleasant things that happen from mining, and asking 'What are we going to do? I prefer to ask 'How are we going to manage the set of resources we have in front of us? How are we

[1] After a steady increase since 1970, China's energy production in the year 2000 increased rapidly from 1 million kilotonnes (kt) oil equivalent to reach 2 million kt oil equivalent by 2010.

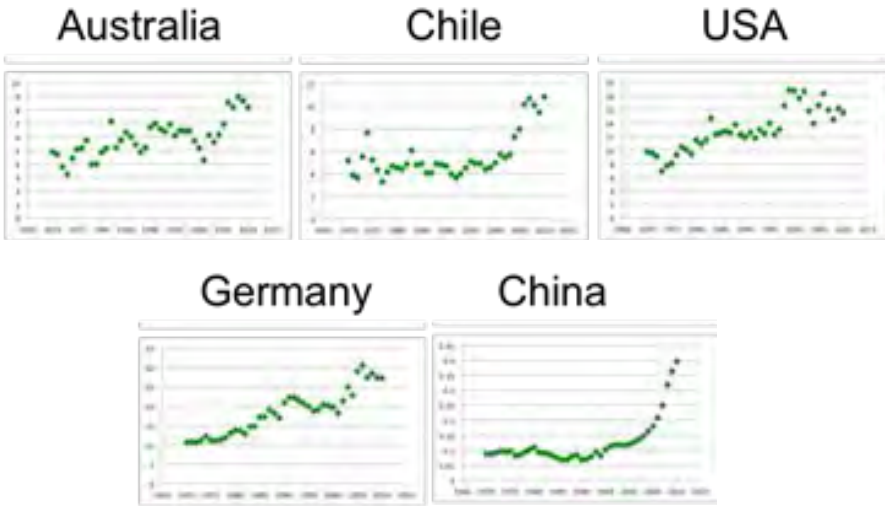


Figure 2. Ratio of GDP of mining (y axis) to agriculture (x axis) in a range of countries from 1970 to 2012.

going to come up with constructs to tackle potential competition? It is certainly feasible.

Mining and agriculture compared

It is interesting to look at the relationship between mining and agriculture across a range of countries (Figure 2). In most of the countries shown, mining has become of increasing importance with time, albeit not at a smoothly increasing rate. The effort of China to produce more minerals can be seen in the steep increase. Unlike some of the other countries, the reason is not global prices but rather a reflection of that drive to develop, which I described above. The step rise in recent years in Australia and Chile, for example (Figure 2), is a reflection of booming prices, also driven by Chinese demand realising supply. It is unsurprising that countries have encouraged mining, reflected by investment and government decision making.

It is equally interesting to look at the relative impact of Australia as an export nation in terms of our involvement in development and overcoming poverty. Australia produces about 1.5% of world wheat, according to ABARES (2011). If we were to export all that into developing countries we could meet, also according to ABARES data, around 20% of those countries' needs. So where do we export to? Well, we export to the USA, European Union, Japan, Korea, the Middle East and Indonesia. We are not actually targeting our exports to feed the poor at the moment.

There a series of arguments that say if we were not feeding these wealthy markets then someone else could not feed the other markets. Nonetheless, as a country with mining–agricultural warfare apparently on our doorstep, what are

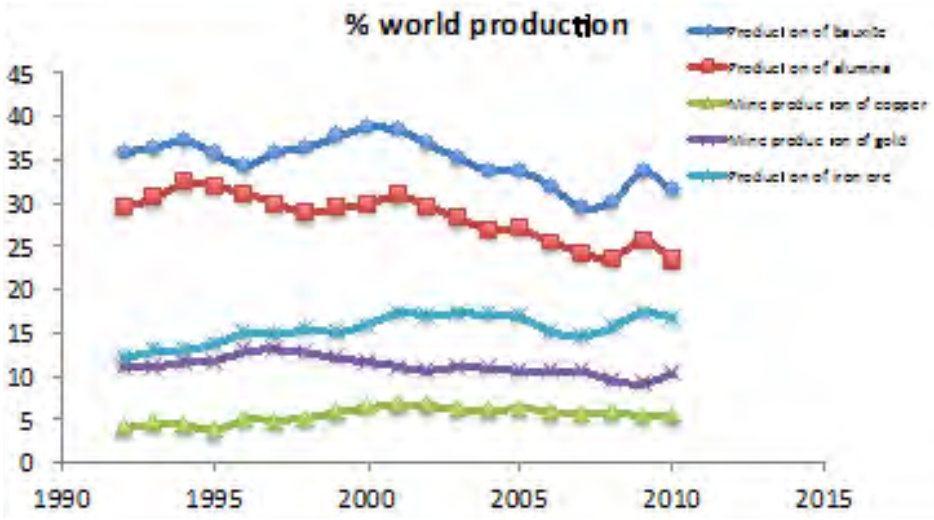


Figure 3. Australian contribution (%) to world supply of various metals: (top to bottom) bauxite, alumina, iron ore, gold, copper.

we doing with the main food that we do produce? We are sending it to wealthy countries. Why? Well they pay, and they pay well. So there is a good economic return to Australia; it is a sensible thing for us to do in our economy.

Cotton is a little different. We do send a lot of cotton to China. It is not food; I understand that it is not food; but it does start to focus on the range of human needs — warmth and clothing. One reason for looking at this alternative need is because it is in some of the irrigated cotton areas that Australia has some issues currently between mining and agriculture. Interestingly, the exports of cotton are quite volatile so our impact on the world is quite volatile.

Now, compare Australia's contribution to the world's supply of metals (Figure 3). For a number of the commodities, we produced a large proportion of the world's needs in 2010, with much of it going into developing countries including China and India. Growth in production has been happening in mining since the 1990s, even though our share of world demand has not grown at the same pace. Iron ore and gas have shown more or less linear growth. We can expect gas to change quite dramatically in the next decade, as a result of offshore gas and coal seam gas coming online in significant quantities. And why do we do that? Well for the same reason.

Figure 4 shows a rather radical increase in the amount of revenue flows — this is only mineral flows; it does not include the energy flow. If you add the exported coal on top of that in particular, you see a significant difference.

What if we put these things together — food, fibre, energy and metals? Why separate them? When we put these things together we can start to ask 'Well where is the base of this economy, and how might we manage the resources that we have, in an integrated fashion?'

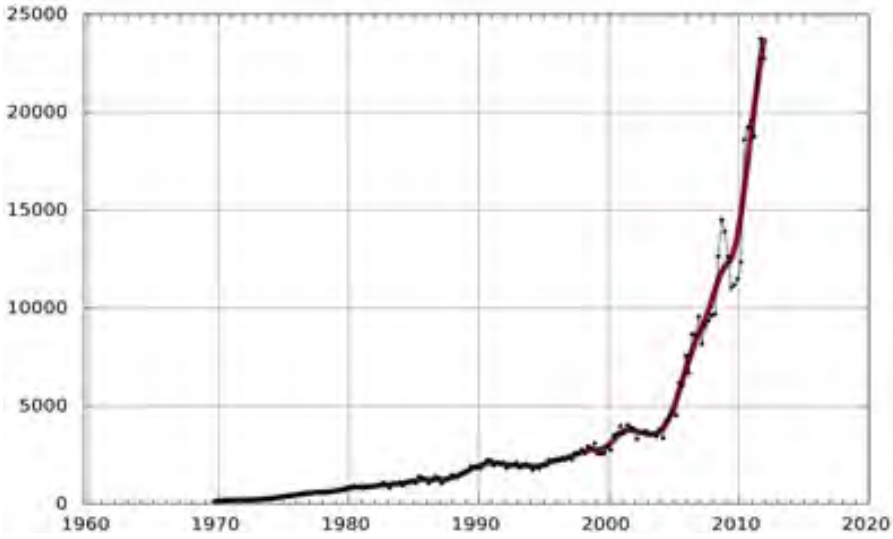


Figure 4. Historical revenue flows from non-energy mining in Australia, in $millon per annum.

An important part of this overall debate is the use of land resources, and land requirements. Figure 5 shows what Australia has been doing with wheat and with cotton. For wheat there was a huge dip in land use around the 1990s, but by 2010 the land required was around 14,000,000 hectares. Now consider how big a mine is. Mines overall may occupy several thousand hectares, but that is a couple orders of magnitude different from the land footprint, the direct land footprint, from wheat.

There are still 'downstream' and 'flow-on' issues, but I do not think there is any argument that the downstream impacts of, for example, a mine and the downstream impacts of agricultural production are fundamentally more or less the same. There are different processes: for instance, mines create voids and agriculture erodes precious surface soil. There are also some similar processes: agriculture acidifies thousands of square kilometres of subsoil and mining can

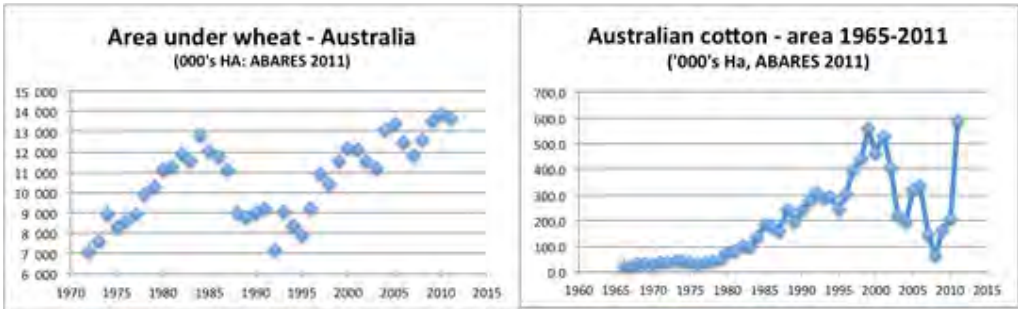


Figure 5. Land area consumed for production of cotton and wheat.

acidify spoil heaps and tailing facilities. Where mining and agriculture exist together they tend to contribute their beneficial and their ill effects together. These are not value judgements; they are measurable and manageable physical and biogeochemical processes.

Social impacts

Where does mining happen in Australia? To what extent are there real issues of overlap and competition? The majority of places that produce large quantities of minerals are actually a long way from agriculture and a long way from water resources that we use for agriculture. We have one very clear and strong example of overlap, and that is in the Hunter Valley in New South Wales. The problem here is that government has permitted major-scale intrusions (mining and other activities) into a landscape, one by one, and we have not stepped back as a society and a government and said: 'Should we look at the collective of what we're doing here?'.

We did the same thing in developing broad-scale agriculture all across the nation. In Australia we just seem unable to step back from these situations and take a simple look at what is going on — and the Hunter Valley is a rather good example of what can happen as a result of that.

My research group has conducted some studies in the Upper Hunter Valley in the Musswellbrook area on the cumulative impacts of mining. We found that the visual impact of mining, the ever-present vista of spoil heaps and roads and dust, created a sense in people that mining was overdeveloped. It was not necessarily that mining companies were not managing the issues at a local level.

Across the town the cumulative impact steadily grew over time, and we saw this by aggregating all complaints data from five mines and comparing that to estimates of visual amenity. It is not always the physical degradation issues that people respond to. What we found was a visceral response: the trigger is the blast, or the light, or the change, or the fact that people see it when they drive around town. Underlying that is the feeling: 'I don't want this amount of activity, this kind of visual assault on me all the time'.

I am not trivialising this issue. It is important, but it is not a 'feeding people in Africa' issue. It needs to be treated properly in proportion to its scale for Australia.

It is important to include coal seam gas in this paper. Coal seam gas changes our view. Its footprint is more like that of a millipede than an elephant, distributed among other land uses across a large area. It presents a new resource-management challenge.

I pose a question: 'Has there ever been a resource-based activity in Australia that could impact tens of thousands of square kilometres, profoundly change the character and availability of underground and surface water resources, generate large quantities of brine on land and in rivers, revolutionise infrastructure and change the face of communities?'

Yes, it is called irrigated agriculture, and I think we probably have not managed it as well as might have. Surely we can learn from exactly that experience and start to ask some of the right questions, instead of trying to set up battle lines!

Conclusion

In conclusion, here are a few summary points.

- Mining is a minor competitor for land (and water) with food production (to meet development needs) *especially compared to food production itself* (e.g. land degradation and 'nationalism').
- Emotional and other social issues abound beyond economic value and land resource occupancy.
- Coal seam gas (and shale gas) production is a new natural resource challenge and an important opportunity for Australia. We are not performing well in the introduction of this resource into our economy.
- Over-generalisation and alarmist communication of potential impacts is not good application of knowledge. It is not evidence-based and it is not going to assist in improving governance and achieving good outcomes. It is certainly not science. There is a critical need for focus.
- Co-resource exploitation, e.g. of soil and gas together, can convert marginal entities into economically successful entities. It is not beyond our capability or knowledge to manage multiple resource extracting activities in parallel. It may, however, be beyond our political capability and our social maturity.

References

ABARES (2011). *Australian crop report.* Canberra, December.

Maslow, A. (1954). *Motivation and personality*. New York, NY: Harper. pp. 236. ISBN 0-06-041987-3.

Professor Chris Moran is Director of the Sustainable Minerals Institute at the University of Queensland and a Member of the Management Board of the newly established International Mining for Development Centre. Prior to working at SMI, Professor Moran spent 16 years with CSIRO where he specialised in spatial science. With more than two decades experience in natural resources and water management and sustainability, his expertise is recognised internationally. He serves on various government panels and committees, as well as UQ boards. As the SMI Director, Professor Moran is responsible for research into all aspects of the life of a mine. His vision is to integrate the Institute's existing disciplinary excellence into NextMine, which will address the complex and multi-faceted challenges facing the resources industry.

Email: chris.moran@uq.edu.au

Landscape urbanisation and food security

Professor Xuemei Bai
Fenner School of Environment & Society
The Australian National University

Abstract

This talk will explore the crucial linkages between urbanisation and food security, based on our recent and ongoing research studies. Urbanisation is often cited as one of the significant factors threatening food security. First of all, urbanisation leads to land use conversion from agricultural land to urban land use, such as for infrastructure, industrial, residential or commercial uses. Such land use conversion often reduces the most fertile land, and therefore the impact on agricultural production and food security is often larger than the absolute amount of land involved. Our recent research shows that such urban land use conversion is often driven by economic factors, with positive feedback loops between urban land use expansion and economic growth in the city, as well as in the region. In addition, urbanisation also brings about changes in dietary structure, which in turn brings about changes to peri-urban areas, where crop production is replaced by higher economic-value products such as vegetables, flowers, fish ponds, and so on. Furthermore, land use changes associated with urbanisation in developing countries are found to increase social vulnerability in the traditional farming communities in the peri-urban areas. On the other hand, some of our initial research results show that urbanisation might have some positive impacts on agricultural productivity. While all evidence seemingly points to close urban–rural linkages, research and policy approaches often treat cities and rural areas as separate sectors. Such dichotomised concepts and approaches hamper the search for an effective system-wide solution. There is a strong need to consider urban and rural areas as integral parts of a system in the global food-security debate or in urbanisation policy. The challenge then becomes to find how we can harness and maximise the positive effects that urbanisation can bring, and avoid or compensate for the negative impacts.

This paper discusses three aspects of landscape urbanisation and food security. First, it introduces some basic facts about urbanisation, which is an unprecedented transition in human settlement that we are experiencing right now. Then it reports on urbanisation impacts on agriculture, both as direct impacts on agricultural land and as indirect impacts on agriculture through various mechanisms. Third, it proposes a change in thinking, away from the current urban–rural dichotomy and towards integrated research and policy.

It is well known that more than half of the Earth's population are urban dwellers and that the proportion is increasing. United Nations projections show urban

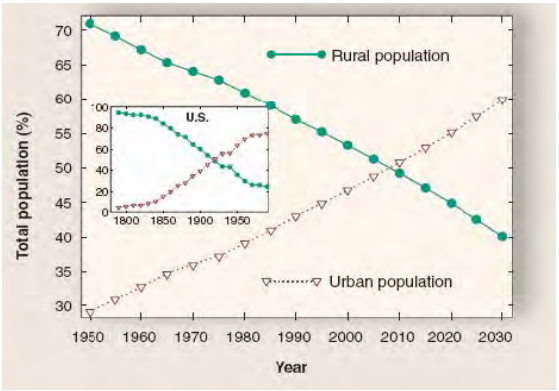


Figure 1. Urban vs rural world populations (Grimm et al. 2008).

populations growing by 1.35 billion by the year 2030, and by 2050 almost all the additional people — about two billion — are projected to live in urban areas. On that basis, the vast majority of the world's people will be urban dwellers by 2050; see Figure 1 for example. As Klaus Töpfer[1] said in 2006, 'the battle for sustainability will be won or lost in cities'.

Consider the major urban centres in the world and their growth rates. Most of the fastest growing cities are located in the developing world. During 1970–2011 in China, in India, and parts of the Middle East and South-East Asia and the sub-Saharan region of Africa, a number of cities grew at from 3% to more than 5% per year. Growth rates of up to 5% were also seen in cities across South and Central America and in some parts of USA. However, urban growth in most cities of the developed world — that is in Europe and the USSR or Russia, and

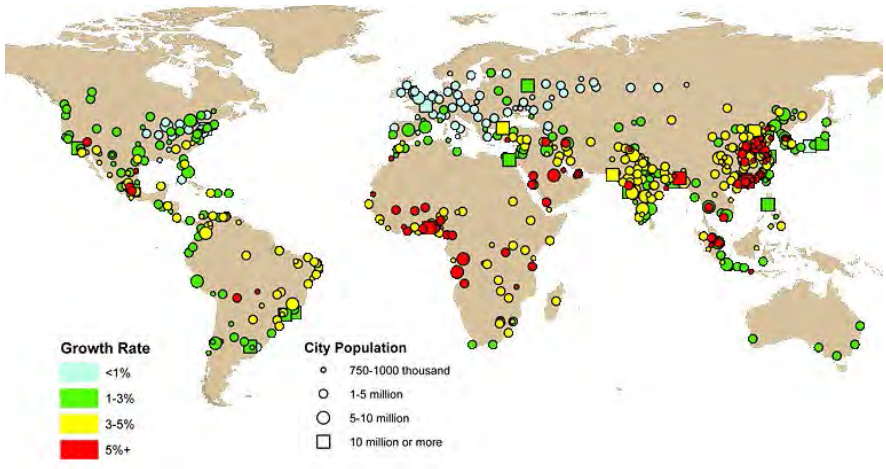


Figure 2. Annual growth rates of urban agglomerations, 1970–2011 (UNDESA 2012).

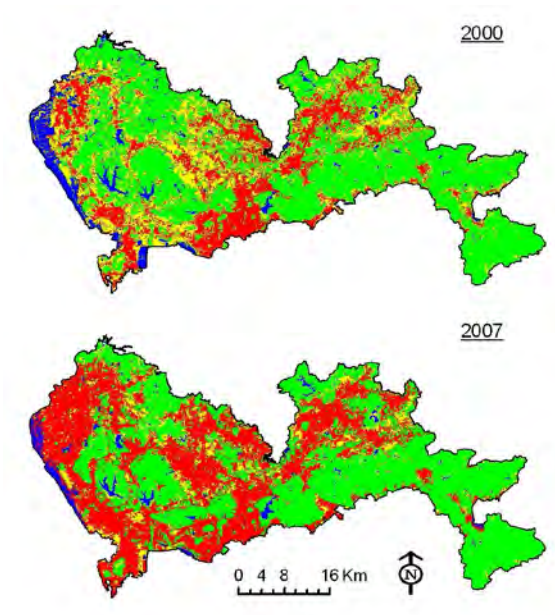
[1] Executive director of the UN Environment Programme in 2006, opening a world congress in Cape Town on local solutions to global environmental problems.

Figure 3. Shenzhen in 1980, a mainly rural landscape with villages (left); the same area in 2005, showing the very rich modern city with over 10 million people (right).

the USA, coastal South America and Australia — was at rates of <1–3% per year (Figure 2).

Of course urbanisation is not only achieved through the expansion of existing cities, but also through the increasing number of cities. In China, until 1978 there were fewer than 200 cities, but over the next 10–15 years the number of cities grew steeply and has now reached about 660, and stabilised (Bai 2008).

Figure 3 helps in visualising what these sorts of numbers and trends mean on the ground. At left is a photo taken in Shenzhen, just across the China–Hong Kong border, in 1980, and it shows that the landscape was predominantly rural with scattered villages involved in agriculture as well as fishery. At right is the same region in 2005 — seven years ago — taken from exactly the same spot. Shenzhen today has a population of over 10 million and is also one of the richest cities in China. So when we talk about urbanisation in China and in developing countries, this is the kind of scale, magnitude and speed we are talking about.



Growth at this scale is still continuing. Figure 4 shows Landsat satellite imagery of the land-use around Shenzhen in 2000 and 2007. The red colour indicates urban land-use. Even within this short seven-year period there was a large increase in the urban area.

Figure 4. Landsat imagery of land-use around Shenzhen in 2000 and 2007, showing the expansion of urbanised land (red colour) (Bai et al. 2012).

Shenzhen is an extreme example, but it is not exceptional. Urban land use in China grew strongly during 2004–08 at the provincial level, which includes cities and designated towns. In some relatively remote provinces, urban land use expanded at less than 8%. However, in the vast majority of provinces, urban land use grew at 8–26%, and in some provinces in south-east China the growth rates were larger than 26% (He et al. 2012).

Such rapid growth of urban land is of particular concern for China and probably for world food security as well, because China is feeding itself with less than 40% of world average per capita arable land. Therefore, rapid uptake of arable land for urban land use can really affect the food security in China and probably in the world in the long run.

Implications for agriculture

Looking at urban land expansion more broadly, the total land taken up by major urban centres and cities is currently about 1% of the Earth's surface (UNDESA 2012). Some forecasts suggest that the amount of land in cities could triple by 2030, but that still does not seem a really large amount of land. However, urbanisation has significant implications for agriculture because it takes over arable land that could otherwise supply food. In fact, because most cities are located in the most fertile land on our planet, urbanisation of that very fertile arable land has a disproportionately high impact.

Other implications for agriculture come from the strong fundamental driving factors behind this kind of urban land expansion, which are very difficult to address. There are also indirect impacts on productivity and rural communities because of urban land expansion. Further, urbanisation is much more than just a demographic change; it changes the quantities and structural mix of the demand for food, and it changes lifestyles, all of which have significant impacts on agriculture. Finally, as mentioned above, there will be very strong pressure on food production concentrated in vulnerable or heavily populated regions in the world, such as China, India and Africa.

In China up to 80% of all agricultural land lost over the last decade was converted to urban areas. Between 1997 and 2006 more than 12,000 km^2 of land was converted into urban built-up areas (Bai et al. 2012). This has a strong effect on arable land because most urban centres are surrounded by arable land. For instance, in the Beijing-Tianjin-Tangshan area all non-urban land within a 10 km radius of each urban centre is arable (Tan et al. 2005).

Urbanisation correlated with economic growth

To try to do something about this trend of arable land loss, it is important to understand the fundamental factors behind such expansion. Working with colleagues I have recently examined long-term data on 191 major cities in China, to look for the factors influencing such rapid urban growth (Bai et al. 2012). We find that larger cities and richer cities appear to be growing more and getting richer faster. We also conducted a Granger causality test to see what is driving this trend. Our results show that larger cities tend to gain more income, and

richer cities tend to expand more. There is a strong long-term bidirectional causality between urban built-up area expansion and gross domestic product per capita, at both city level and at provincial level, and there is short-term bidirectional causality at provincial level. This means there is a positive feedback between landscape urbanisation and urban and regional economic growth in China.

This means that urbanisation, if measured by landscape indicators, has a causal effect on economic growth in China, both within the city and, through a spillover effect, in the region. Urban land expansion is not only the consequence of economic growth in cities, it also drives such growth. Under the current economic growth model in China, it may be very difficult for China to control urban land expansion without sacrificing economic growth. That is a really tough situation in which to make decisions. It means that China's policy of stopping the loss of agricultural land, for the sake of food security, might be strongly challenged by its policy of trying to promote economic development through urbanisation (Bai et al. 2012).

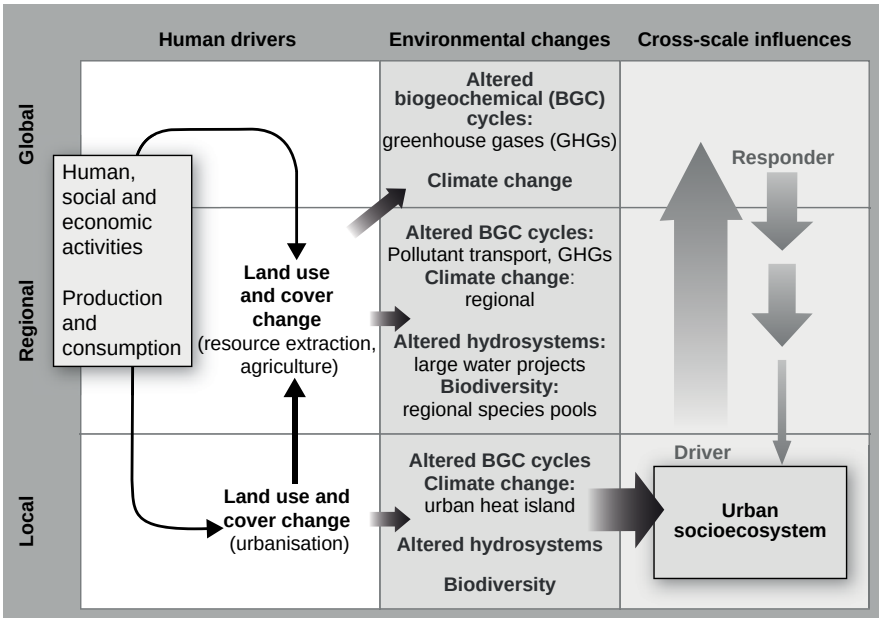
Indirect implications for rural areas

There are also indirect impacts on productivity and rural communities. With colleagues in China, I have examined how land use expansion affects rural communities in China. We find that land use changes associated with urbanisation have increased the social vulnerability of traditional farming communities in the peri-urban areas (Huang et al. 2012). The vulnerability can last for up to 20 years before it levels off or increases further. In those 20 years, a new generation grows up and people can be integrated into the urban fabric and start new kinds of livelihoods. There are large impacts from urbanisation.

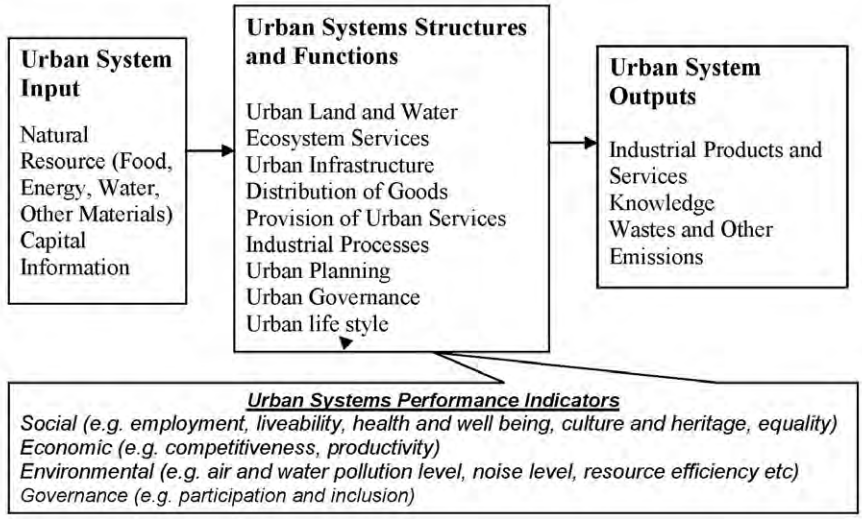
In other areas of China, the locals have seized the opportunity offered by urban areas. In those areas there is a very big increase in social and economic capital in peri-urban areas (CCICED 2012).

The impact of cities extends beyond their physical footprints. Figure 5 is a conceptual diagram which shows that activities happening within cities are driving environmental changes at local, regional and global levels, and that these changes have a feedback effect on cities and force them to respond to the changes. Cities are responsible for most of the carbon emissions (78%) and most of the residential water use (60%), and 76% of wood used for industrial purposes.

Another way to understand the global impact of cities is to consider a city's 'urban metabolism': think of a city as a type of organism or system (Figure 6). Cities require considerable inputs from surrounding areas, including food, water and energy, and these are distributed within the cities and contribute to the functions and processes within cities. Then eventually there are by-products and outputs from the urban systems. Figure 7 is a conceptual model of the urban dietary flow of phosphorus (P), moving into the city in food, through the city via various pathways including people, and out into the environment (Li et al. 2012).



Figures 5 (above) and 6 (below). Interactions and feedback loops that link cities and their environments, including surrounding rural areas: inputs and waste products (outputs), and factors and responses (Grimm et al. 2008; Bai & Schandl 2011).



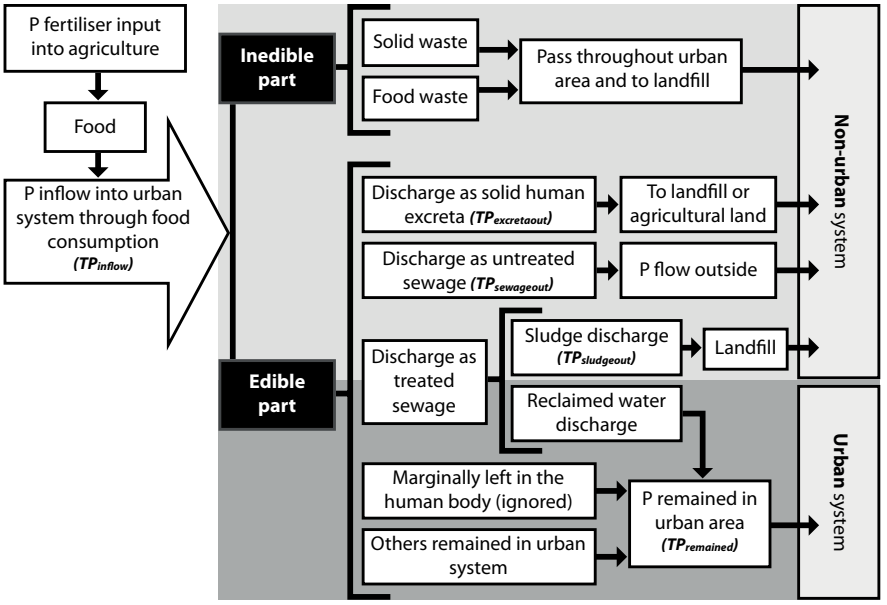


Figure 7. Conceptual model of the flow of dietary P (phosphorus) into and out of an urban system (based on Li et al. 2012).

On the input side, what happens within cities can significantly change the demand for food and the amounts that are imported into cities. I saw this question and answer on a Chinese website:

What's growing faster than the Chinese economy? The Chinese people's waistlines!

In fact, the answer refers to urban people's waistlines, not those of the whole Chinese people, indicating increasing food consumption by urban populations. There is an explosive growth of fast food stores in Chinese cities, including McDonald's. Urban people are consuming more meat, more fish, more dairy products, which in turn requires much more animal feed to support such a dietary change.

Now consider the output side. Our studies on urban phosphorus metabolism via food system shows an increasing amount of phosphorus metabolism through all cities, but their pathways can vary significantly. The graphs in Figure 8 support that point that what cities do, how rich they are and what they do about wastewater treatment and other wastes can strongly affect how much material they export into the surrounding areas, polluting the water and affecting the agriculture there (Li et al. 2012).

Towards an integrated approach

In conclusion, this paper has shown that what happens in agriculture may largely be driven and determined by what happens in cities. Most of the literature looking into food security blames cities as culprits affecting food security. Yet

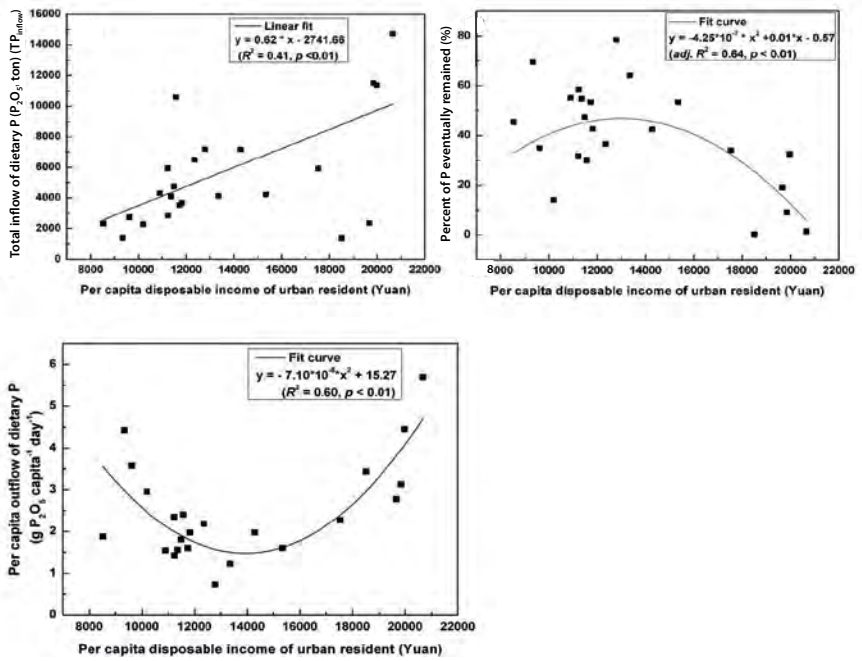


Figure 8. Relationship between per capita disposable income of urban residents and indicators related to dietary P flow in provincial capital cities of China (data for year 2006; Li et al. 2012).

simply blaming cities in that way does not help solve the problems. Urban issues are largely ignored in research into sustainable food production, as well as in policy-making — and equally, within the urban development research sector people pay very little attention to agriculture.

Urbanisation brings opportunities as well as challenges, and the question is: how can we harness and maximise the positive effects brought by urbanisation, and also avoid and compensate for the negative impacts?

We need a good understanding of the inter-linkages between urban and rural, or urban and agricultural systems. There is a very strong need for an integrated approach, rather than the dichotomised approach that is the norm today, in research and policy for urban development and for the food production debate.

References

Bai X.M. (2008). Urban transition in China: Trends, consequences and policy implications. In: Martin G., McGranahan G., Montgomery M. & Fernández-Castilla R. (Eds) *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century*. EarthScan, London, pp. 339–356.

Bai X.M. & Schandl H. (2011). Urban ecology and industrial ecology. In: Douglas I., Goode D., Houck M. & Wang R. (Eds) *The Routledge Handbook of Urban Ecology*. Routledge, pp. 26–37.

Bai X.M., Chen J. & Shi P.J. (2012). Landscape urbanization and economic growth: Positive feedbacks and sustainability dilemmas. *Environmental Science & Technology* 46(1): 132–139.

CCICED (2012). *Taskforce Report: Strategy and Policies on Environment and Development in Western China*. China Council for International Cooperation on Environment and Development. Presented to Vice Premier of China Li Keqiang and other top leaders, December 2012. 69 pages.

Grimm N.B., Faeth S.H., Golubiewski N.E., Redman C.L., Wu J.G., Bai X.M. & Briggs J.M. (2008). Global change and the ecology of cities. *Science* 319: 756–760.

He C., Huang Z. & Wang W. (2012). Land use changes and economic growth in China. *Land Lines*, 2012. October.

Huang Y., Li F., Bai X.M. & Cui S. (2012). Comparing vulnerability of coastal communities to landuse change: Analytical framework and a case study in China. *Environmental Science & Policy* 23: 133–143.

Li G.L., Bai X.M., Yu S., Zhang H. & Zhu Y.G. (2011). Urban phosphorus metabolism through food consumption: The case of China. *Journal of Industrial Ecology* 16(4): 588–599. DOI: 10.1111/j.1530-9290.2011.00402.x.

Tan M. et al. (2005). Urban land expansion and arable land loss in China — a case study of Beijing–Tianjin–Hebei region. *Land Use Policy* 22(3): 187–196.

UNDESA (2012). *World Urbanization Prospects, the 2011 Revision*. New York: United Nations Department of Economic and Social Affairs, Population Division.

Xuemei Bai is a Professor of Urban Environment and Human Ecology at the Fenner School of Environment and Society at the Australian National University. Her work focuses on urbanisation and the environment, including drivers and impacts of urbanisation,urban system function and processes, urban environmental governance, cities and climate change, and innovative urban practices and urban sustainability transition, mostly in Asia. She is Vice Chair of the Scientific Committee of the International Human Dimensional Program for Global Environmental Change; Board member of the Sustainable Urban Systems Chapter in the International Society of Industrial Ecology, and a Foreign Expert member of the Task Force for Western Region Development under the China Council for International Cooperation for Environment and Development.

Email: Xuemei.Bai@anu.edu.au

Forest lands: More than just trees

Dr Christine Padoch
Center for International Forestry Research (CIFOR)

Abstract

Global rates of deforestation and forest degradation continue at persistently high levels, although annual net rates of forest loss have slowed to approximately 8 Mha as the extent of planted forests increases. Drivers of deforestation vary geographically. Conversion to both large- and small-scale agriculture remains dominant, and conversion to plantations, mining and infrastructure development is important in some regions. Forests, however, continue to be important to the livelihoods of millions of people, poor and rich, men and women, rural and urban. They provide a broad range of products that often escape the attention of decision makers, and an even broader range of services that are both poorly understood and commonly ignored. The direct contribution of forests to livelihoods varies widely with region, community, gender, ethnicity and management system. Research done by CIFOR with 50 research partners in over 8000 households living in and around forests in 25 developing countries shows that forest-derived income constitutes about 20% of their total household income, while income from the environment more generally — both forest and non-forest — makes up more than 25%. Globally, the most important part of that income comes from the sale of fuelwood, with timber sales second. The direct contribution of forests to diets is also considerable and often crucial, but largely hidden from urban and official eyes. Forest foods add not only calories but also necessary protein and micronutrients to the diets of rural people. The importance of forests' direct contribution to diets and incomes may be eclipsed by their inputs to human well-being outside forests. Focusing on food, much more needs to be understood about the environmental services that forests provide to various types of agriculture, including the regulation of water flow and quality, mitigation of climatic extremes, provision of pollination services and germplasm for crop improvement, maintenance of nutrient cycling and soil fertility, control of agricultural pests and diseases, and other essential functions. These services are critical to the maintenance of most agricultural systems, including the most modern agribusinesses, but are seldom valued until they are lost. Knowledge of how forests can be managed to simultaneously optimise production of foods and environmental services is also little understood and thus little valued. Without proper attention to these issues, the importance of forests to human well-being will continue to be undervalued, ignored, and diminished, increasingly irreparably.

Forests support food security

There is general agreement about the importance of forests. As other speakers today have said, it is important to preserve forests despite the fact that we need to increase food production.

Putting a different spin on that concept, this paper says we need to preserve forests *because* we need to increase food production. The reason is that a large amount of agricultural production and a large amount of the other food that people — especially the most vulnerable populations on the globe — use and depend on, actually depends on forests.

Usually, agriculture and forest conservation are presented as antagonists. For a poor country that is grappling with extremely high food prices but has extensive forests in its territory, it might seem that the most reasonable — and perhaps the only — solution to that situation is to clear the trees. Again, for a developing country that wants to step up to become a richer country, and that has an opportunity to use large areas of its land to grow valuable food crops, it might also seem that clearing the forest is the best solution. In situations like those, food security and conservation of forests seem to be a zero-sum game. For many many major countries this is not a theoretical question but an actual dilemma. Countries that have faced this dilemma in the past, or are facing it now, include Indonesia, Brazil, Peru, the Democratic Republic of Congo, and many others throughout the tropics. They try to come to a decision about it in very different ways. How and where those decisions are made has a lot to do with both the conservation of forests and the conservation of environmental values, and also with the conservation of our ability to keep on producing food.

This kind of dichotomist discourse appears also beyond those countries' borders, in the international arena. However, this paper aims to show that, wherever it takes place, it is a very narrow and limited view of what is possible. Instead, we really need to understand that there is no necessary dichotomy; agriculture and forest conservation need to come together because food security now and in the future actually depends on forests being conserved.

As you will have heard particularly during 2011 the United Nations International Year of Forests, deforestation rates are still high and degradation rates are also still high. The good news is that there has been a significant decline in global net rates of deforestation. That net decline in changes in forest cover is largely due to the expansion of planted forests. There are several issues here: one is that some of those planted forests will not have all the qualities that can be expected to come from more natural

forests or little disturbed forests. Another problem is that there are increased pressures on those forests, such as for expansion of agricultural production or other land uses that many countries are now developing.

There are very large and interesting differences regionally in the rates of deforestation — that is, the rates at which net deforestation is coming down or not — and also in the causes of those different rates of deforestation. Details are available at the CIFOR website[1]. Nevertheless, the fact that deforestation continues at all shows that the true values of forests have yet to be understood, and particularly that the true value of forests in relation to food security is still to be appreciated.

The reality is that at least a billion people in the world depend on forest resources for their daily needs. A billion people is every seventh person on Earth, and among those people who depend most directly on these resources are some of the people who are the most vulnerable, whether because of the

[1] www.cifor.org

countries or regions in which they live, or because of gender, or because of various other issues. Many of these billion people are members of indigenous groups, and many of them are minorities in the countries in which they live. Cutting down their forests in the name of greater food production would actually hurt the nutritional status of many of these people and have long-lasting negative effects on their agriculture and on their other resource use.

Benefits of forests overlooked

Preliminary results from a six-year CIFOR study that just ended, called PEN, the Poverty and Environment Network, give us a glimpse of the importance of forests for livelihoods. The CIFOR website and publications are progressively reporting the results of the PEN study, which seems to be the largest of its kind so far. The study involved 50 research partners in 364 communities around the globe, and recurring research over time with about 8000 households.

For households that are located near or within forests — which includes a surprising number of areas of the globe — the preliminary research shows that forest income contributes more than 20% of their total household income, and that is just in areas that are classified as forest. Adding in other environmental income, such as from products of areas that are largely natural but not necessarily classified as forests, that proportion rises to more than 25% of total household income. Now 25% may not seem overwhelmingly important, but for those communities and those households it is actually more than they get from planted crops.

Also within this global data set there is information about sources of income for women and ways of providing income to the people who are the most vulnerable. For example, consider Burkina Faso, one of the poorest countries on the planet and an area quite typical of dry West Africa. Women in Sissili Province there have few sources of direct income, and, in contrast to some

of the income that men bring into the household, women's incomes tend to go towards feeding the family (Thomas et al. 1990; Duflo & Udry 2004). In three case-study villages, women derived 53% and 46% of their usable income from forest products in two of the villages, and 12% in the third village. These data show that within the global picture of 25% of income from forests and forest-like areas there are some more localised examples of people for whom forests provide much more than a quarter of their daily needs.

Why are important forest-based contributions such as these not valued? One reason is that many of the existing tools for assessing poverty, including statistics on an international level and many of the numbers generated by the World Bank, actually do not capture the importance of these forest products. Much of the activity of people who live near forests, actually inside or at the edges of these forests, falls between the conventional definitions of what is agriculture, what is forestry, what are forest products, what is food. Therefore they tend not to enter into national or international statistics. Many of the forest people and their livelihoods are really quite inscrutable and invisible to those who gather national and international statistics. This means their importance tends not to be understood, and they tend not to figure in the policy decisions that are made, either at national or at global levels.

Forests need to be valued. Food security means satisfying not just the need for calories but also the need for nutritious diets. Stunting of children occurs not because they have too few calories — in many areas calories are actually not a problem — but because they lack micronutrients. The deficiencies are in vitamins and in proteins. Our current studies show that for a majority of children under five in 21 African countries, there is a positive correlation between the percentage of tree cover in their communities and their dietary diversity (Ickowitz et al. pers. comm.). Millions of children around the world go blind every year from lack of vitamin A (WHO 2003, 2012); yet forest products supply that essential need. Vitamin A and iron are among the important micronutrients that come largely from the forest for many communities (Golden et al. 2011; Powell 2012). That is true not only for remote rural communities, but also for many other areas including some newly urbanised places.

Another forgotten but important forest product is bush meat. Five to six million tonnes of bush meat are eaten annually in the Congo Basin, and

that is roughly equivalent to the total amount of beef produced each year in Brazil (Nasi et al. 2011). It is produced in the Congo without the deforestation that occurs in Brazil. For many communities this is up to 80% of their intake of protein and fats. That is something that is hardly heard about — instead we hear about the criminalisation of hunting — but bush meat is extremely important locally.

Yet, the services that forests provide to agriculture completely eclipse these direct food subsidies that come from forests. Forests provide water services, by regulating and filtering water. They provide pollination services and temperature regulation, both on a global scale and on a local scale. The latter is especially vital in the face of climate change. They produce aquatic resources — consider how many aquatic resources come out of floodplain forests and out of mangroves — and genetic resources, and so forth; the list goes on. We still know very little and understand very little about these services.

So, what can we do to address food and income security while also protecting forests, understanding that without forests probably we will have less secure food supplies?

Integration and governance

Obviously, there is no 'silver bullet'. Agricultural intensification on land that is already under cultivation is essential. Sustainable increases will demand all kinds of improved practices, but just sustainable increases, sustainable intensification on limited areas of land, are probably not enough. A landscape approach, which looks at food production over an entire diverse landscape that includes forest, is the most promising way forward. Investments in agriculture must be coupled with improvements in forest use and governance.

Good forest governance is key. If areas are going to be cut down it is extremely important to involve the people who live there and own those forests or use those forests. It is vital also to take into account the environmental services that forests provide to global agriculture and society at large.

Forests and forest lands are more than trees, and forests represent more than just land for agricultural expansion. Keeping forests as forests within diverse functional and productive landscapes is a challenge that we all face. It is essential that we win that challenge if we are to maintain the services that forests provide, including both direct and indirect contributions to food security.

References

Duflo E. & Udry C. (2004). *Intrahousehold resource allocation in Cote d'Ivoire: Social norms, separate accounts and consumption choices*. NBER Working Paper 10498, National Bureau of Economic Research. USA: Cambridge, MA.

Golden C.D., Fernald L.C.H., Brashares J.S., Rasolofoniaina B.J.R. & Kremen C. (2011). Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *PNAS* 108(49): 19653–656.

Ickowitz A., Powell B. & Sunderland T. (pers. comm.) Forests and child nutrition in Africa. Submitted for publication.

Nasi R., Taber A. & Van Vliet N. (2011). Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. *International Forestry Review* 13(3): 355–367.

Powell B. (2012). Biodiversity and human nutrition in a landscape mosaic of farms and forests in the East Usambara Mountains, Tanzania. PhD dissertation, School of Dietetics and Human Nutrition, McGill University, Montreal, Canada.

Thomas D., Strauss J. & Henriques M. (1990). Child survival, height for age, and household characteristics in Brazil. *Journal of Development Economics* 33: 197–234.

WHO (2003) *Diet, nutrition and the prevention of chronic diseases.* Report of a joint WHO/FAO expert consultation, Geneva, 28 January – 1 February 2002, Technical Report Series 916, World Health Organization/FAO.

WHO (2012). Vitamin A. deficiency. World Health Organization, Programmes and Projects, Nutrition topics. http://www.who.int/nutrition/topics/vad/en/

Dr Christine Padoch is an ecological anthropologist and the Director of the Forests and Livelihoods Programme at the Center for International Forestry Research (CIFOR) in Bogor Indonesia. She has spent more than 35 years carrying out research on smallholder patterns of forest management, agriculture, and agroforestry in the humid tropics, principally in Amazonia and South-East Asia. Her interests and research pursuits have remained broad and, for example, she has investigated smallholder farming and forest management in the Amazon floodplain, patterns of migration and swidden agriculture in Borneo and small-scale marketing of forest products and marketing networks. She came to CIFOR from the New York Botanical Garden where she was the Matthew Calbraith Perry Curator of Economic Botany. Christine Padoch holds a PhD in anthropology from Columbia University.

Email: c.padoch@cgiar.org

Closing the yield gap through integrated soil fertility management*

Dr Nteranya Sanginga
International Institute of Tropical Agriculture

Abstract

African agriculture stands at a crossroads. Either food security in Africa will remain elusive with isolated successes fuelling a sense of false optimism in an otherwise dismal situation, or decisive action can be taken to assist small-scale farmers to grow more and more valuable crops. Excellent progress is being made in crop improvement and seed systems, and many crop diseases, particularly viruses and fungal leaf pathogens, no longer pose a major problem. Low soil fertility and nutrient depletion continue, however, to represent huge obstacles to securing needed harvests. Improving access to fertilisers is a necessary countermeasure; however, the low returns from unskilled use of these products present a major impediment to their adoption by most small-scale farmers. Integrated Soil Fertility Management (ISFM) is defined as: the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimise fertiliser and organic resource-use efficiency and crop productivity. ISFM represents a means to overcome this dilemma by offering farmers better returns for investment in fertiliser through its combination with indigenous agro-minerals and available organic resources. Disseminating knowledge of ISFM and developing incentives for its adoption now stand as challenges before national planners and rural development specialists. Done efficiently, these will result in more productive and sustainable agriculture, improved household and regional food security and increased incomes among small-scale farmers.

> *The soil nutrient losses in SSA are an environmental, social, and political time bomb. Unless we wake up soon and reverse these disastrous trends, the future viability of African food systems will indeed be imperiled.*
> Dr Norman Borlaug, 14 March 2003, Muscle Shoals, Alabama, USA.

High world fuel and fertiliser prices, increasing production of biofuels and a declining human capacity for soil and natural resource research continentally continue to exacerbate the situation described by Dr Norman Borlaug in the quote above.

---

* This paper is coauthored by P.L. Woomer, and adapted from Sanginga N. & Woomer P.L. (Eds) (2009). *Integrated Soil Fertility Management in Africa: Principles, Practices and Developmental Process*. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 263 pp.

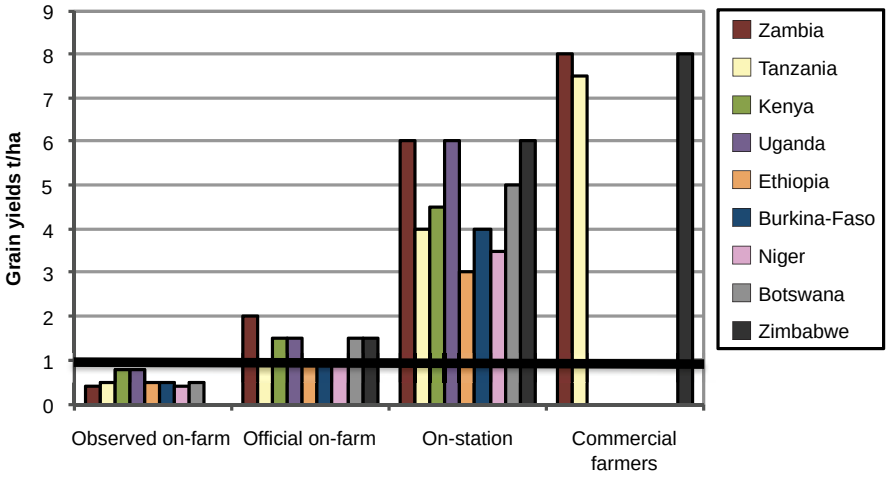


Figure 1. Reported maize grain levels in selected countries in sub-Saharan Africa, indicating the yield gap (heavy horizontal line).

There is, however, growing evidence that meeting this challenge in sub-Saharan Africa (SSA) will require more attention to soil fertility issues than was the case elsewhere. Farmers' fields are characterised by low inherent fertility and low use of inputs (Bationo et al. 2006). In most farmers' fields observed yields for most cereals hardly exceed 0.5 t/ha, yet a potential of 8 t/ha is attained in on-station trials and by some commercial farmers. As a result there is a great yield gap between the experimental station yields, farmers' potential yields and farmers' actual yields (Figure 1).

The high yield gap between farmers' potential and actual yields can be attributed to several constraints, mainly biological (varieties, weeds, disease and insects, water and nutrient deficiencies) and socio-economic (costs and benefits, access to credit and inputs, attitude, among others). Using models and different scenarios, the contribution of soil fertility to the yield gap can be determined. This calls for careful targeting of technology recommendations for potential and profitable soil fertility management, to address the diverse socioeconomic, biophysical and policy factors contributing to the low productivity.

Better management of soil fertility is an imperative for SSA. Pedro Sanchez (1997) identified soil fertility depletion on smallholder farms as the 'fundamental biophysical root cause of declining per capita food production in Africa' and advocated more integrated problem-solving approaches.

Despite these insightful observations the situation has only worsened. We face more than an economic problem because this potentially explosive situation threatens the very fabric of social stability in the poorest countries. In response, soil health issues are rising within the agendas of policymakers and donor agencies.

There has never been a better time to reinforce the relevance of soil fertility research in SSA. For instance, the Head of States during the African Fertiliser

Crops grown using conservation agriculture (left) and organic versus conventional nutrition (right) show the healthy-looking vigour produced by combining organic and mineral nutrition through integrated soil fertility management (ISFM).

Summit (AFS) conducted in Abuja, Nigeria, during 2006, recommended that fertiliser use be increased from the average 8 kg/ha to 50 kg nutrients/ha until 2015. The Bill and Melinda Gates Foundation and the Rockefeller Foundation through the Alliance for a Green Revolution in Africa (AGRA) have decided to invest in a soil health program as part of the African Green Revolution. The AGRA Soil Health Program will help build a foundation for agricultural sector growth by restoring African soil fertility through soil management and fertilisers that stably increase crop productivity by 50–100%.

AGRA believes that roughly half of the huge yield gap existing between SSA countries and the developed world will be closed through soil nutrients and improved agricultural practices; the other half through improved seed. African farmers, therefore, need better technologies, more sustainable practices, improved crop varieties and fertilisers to improve and sustain their crop productivity, and to prevent further degradation of agricultural lands.

African agriculture stands at a crossroads. Either food security in Africa will remain elusive with isolated successes fuelling a sense of false optimism in an otherwise dismal situation, or decisive action can be taken to assist small-scale farmers to grow more and more valuable crops.

Excellent progress is being made in crop improvement and seed systems. Many crop diseases, particularly viruses and fungal leaf pathogens, no longer pose a major problem. However, low soil fertility and nutrient depletion continue to represent huge obstacles to securing needed harvests. Improving access to fertilisers is a necessary countermeasure; but the low returns from unskilled use of these products present a major impediment to their adoption by most small-scale farmers.

The Integrated Soil Fertility Management (ISFM) paradigm as defined below represents a means to overcome this dilemma by offering farmers better returns for investment in fertiliser through its combination with indigenous agro-minerals and available organic resources.

Disseminating knowledge of ISFM and developing incentives for its adoption now stand as the challenge before national planners and rural development specialists!

Table 1. Changes in tropical soil fertility management paradigms and their effects on farm resource management over the past five decades.

Paradigm	Role of fertiliser	Role of organic inputs	Experiences
During the 1960s and 1970s			
External Input Paradigm: '1st Paradigm'	Use of fertiliser alone will improve and sustain yields.	Organic resources play a minimal role.	Limited success because of shortfalls in infrastructure, policy, farming systems, etc.
During the 1980s			
Organic Input Paradigm	Fertiliser plays a minimal role.	Organic resources are the main source of nutrients.	Limited adoption; organic matter production requires excessive land and labour.
During the 1990s			
Sanchez's 'Second Paradigm'	Fertiliser use is essential to alleviate the main nutrient constraints.	Organic resources are the entry point; these serve other functions besides nutrient release.	Difficulties in accessing organic resources hampered adoption (e.g. improved fallows).
During the 2000s			
Integrated Soil Fertility Management (ISFM)	Fertiliser is a major entry point to increase yields and supply needed organic resources.	Access to organic resources has social and economic dimensions.	On-going; several success stories.

The Integrated Soil Fertility Management (ISFM) paradigm

Based upon agricultural research findings across numerous countries and diverse agro-economic zones of SSA, a consensus has emerged that the highest and most sustainable gains in crop productivity per unit nutrient are achieved from mixtures of inorganic fertiliser and organic inputs (Vanlauwe et al. 2001). The ISFM paradigm results from lengthy investigation into the management of crop nutrition (Table 1). ISFM was derived from Sanchez's earlier Second Paradigm that relies

> *more on biological processes by adapting germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling to minimize external inputs and maximize the efficiency of their use.*

Thus, Sanchez recognised the need to combine essential organic inputs with fertilisers, but farmer-available organic resources are viewed as the main entry point (Sanchez 1994). Indeed, combining mineral and organic inputs results in greater benefits than either input alone, through positive interactions on soil biological, chemical and physical properties.

Adoption of the Second Paradigm by farmers was limited by the excessive requirement for land and labour to produce and process organic resources. Farmers proved reluctant to commit land solely to organic resource production at the expense of crops and income.

Integrated Soil Fertility Management (ISFM) may be defined as

> *the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm.*

ISFM is not characterised by unique field practices but is rather a new approach to combining available technologies in a manner that preserves soil quality while promoting its productivity. ISFM practitioners do not merely recite this definition, but plan much of their annual field activities around it. Soil fertility management includes timely and judicious utilisation of pre-plant and top-dressed mineral fertilisers, but also the generation, collection, storage, enrichment and application of available organic resources and the maintenance and enhancement of beneficial soil organisms and processes.

The ISFM paradigm offers an alternative to the Second Paradigm by using fertiliser as the entry point for improving productivity of cropping systems. It asserts that substantial and extremely useful organic resources can be derived as by-products of food crops and livestock enterprises. ISFM also recognises the importance of an enabling environment that permits farmer investment in soil fertility management, and the critical importance of farm input suppliers and fair produce markets, favourable policies, and properly functioning institutions, particularly agricultural extension. Translating this knowledge into practical soil and land management strategies and empowering farmers through participatory technology development and adaptation is key to successful application of ISFM.

Current smallholder practice in Africa is too often exploitive, mining the soil of its nutrients and leading to degraded non-productive farming (Buresh et al. 1997). Simply introducing improved crop varieties and modest amounts of mineral fertiliser can improve crop yields but at a relatively low agronomic efficiency of nutrient use. Combining fertiliser addition with locally-available organic inputs, while retaining or enriching crop residues, improves nutrient-use efficiency and protects soil quality. Thus, several intermediary phases may be identified along the progression from farmers' current practice toward optimised ISFM (Figure 2). Complete ISFM comprises the use of improved germplasm, fertiliser, appropriate organic resource management and adaptations to local conditions and seasonal events. These adaptations lead to specific management practices and investment choices, and are iterative in nature, leading to better judgments by farmers concerning weed management, targeting of fertiliser and organic inputs in space and time, and choice of crop varieties.

Farmers' resource endowment also influences ISFM, as do market conditions and favourable policies promoting farm input supply. Local adaptation also adjusts for variability in soil fertility status and recognises that substantial improvements in agronomic efficiency of nutrient addition can be expected

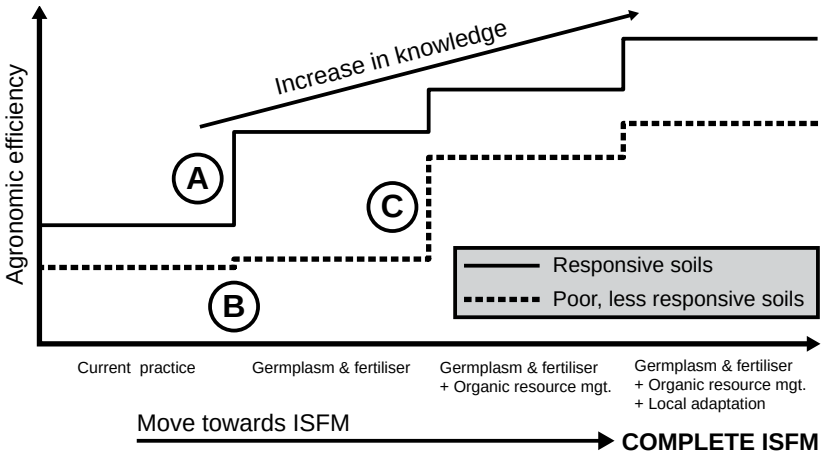


Figure 2. Conceptual relationship between the agronomic efficiency of fertilisers and organic resources, with current practice at left and full ISFM at right. At constant fertiliser application rates, yield is linearly related to agronomic efficiency.

on more responsive soils (A in Figure 2) while on poor, less-responsive soils, application of fertiliser alone does not result in improved nutrient use (B in Figure 2). Fertiliser is better applied in combination with organic resources (C in Figure 2). Additions of organic matter to the soil provide several mechanisms for improved agronomic efficiency, particularly increased retention of soil nutrients and water and better synchronisation of nutrient supply with crop demand, but it also improves soil health through increased soil biodiversity and carbon stocks.

ISFM is effective over a wide range of fertiliser application rates. It can greatly improve the economic returns from achieving the African Fertiliser Summit target through the increase in fertiliser agronomic efficiency, when its use grows from an average of 8 kg/ha to 50 kg nutrients/ha. ISFM also deters land managers from applying fertilisers at excessive rates that result in reduced agronomic efficiency and environmental pollution.

The approach advocated to improve the soil fertility status of African soils is embedded within the ISFM paradigm and will be achieved in large part. Maximum benefits from ISFM practices and technologies can only be obtained within an enabling context, where such factors as viable farm input supply and produce-markets, functional institutions and good policy are in place.

Assessment of ISFM technologies and targeting impact zones

Our knowledge of Africa's soils is relatively small compared to that of the hundreds of million small-scale farmers who make their living from soils management. In our attempts to fill this knowledge gap, however, we have made numerous practical achievements, often with land managers taking the lead. The management of available organic resources by smallholders seeking to diversify their operations and address new markets often demonstrates an intuitive understanding of nutrient recycling.

Most African farmers make innovative use of field and farm boundaries and collect useful organic materials from outside their farms, often by necessity, and then incorporate them into their major farm enterprises, particularly for cereal-based cropping and livestock rearing. Farmers have learned to access mineral fertilisers and to use them in a judicious manner, despite their high cost and competing demands for scarce cash. It is within this agricultural setting that ISFM is taking hold in Africa, leading to more effective combination of organic and mineral inputs to soil and directing them toward more profitable use.

Redirection of soil management practice is best conducted in conjunction with adoption of improved crop varieties that have been specially bred to meet rural household needs. In this way, new cropping systems involving higher yielding staple foods, grown in conjunction with new and improved legumes in rotations and intercrops, can raise the living standards of African small-scale farmers while improving the soils upon which their future depends.

The challenge now before the research and development community is how to replicate and expand isolated successes in ISFM in a manner that rapidly attracts a variety of land managers, and empowers even the poorest farming households to become innovative adopters.

Evaluation of earlier initiatives intended to improve soil fertility management practised by smallholder farmers shows that different interventions contribute in divergent ways to increased productivity and agronomic efficiency of inputs, and have contrasting potential for widespread adoption (Figure 3). Note that the interventions in the upper right quadrant ('High–high') of Figure 3 represent

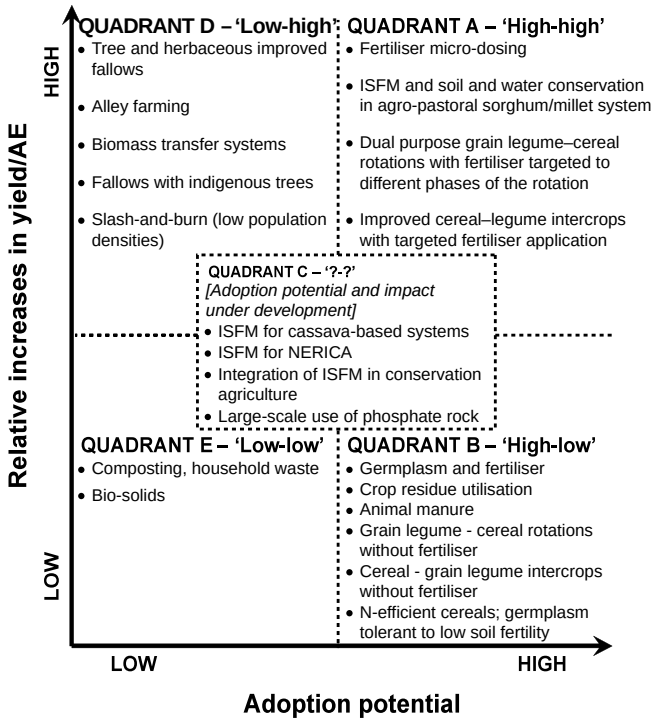


Figure 3. Relative adoption potential and contribution to soil fertility enhancement for various tested soil fertility management interventions. Adapted from A. Adesina (pers. comm.). AE = agronomic efficiency.

practices where complete ISFM as shown in Figure 1 is being successfully employed, and adopted in certain agro-ecological zones in SSA. Technologies in other quadrants are, to lesser or larger extents, moving towards complete application within ISFM. Practices listed within the central quadrant C could become utilised to great advantage, but there is at present limited knowledge on how to adopt ISFM into recommended practice. Note that the choice of winning technologies in the upper right position of Figure 3 is based upon their feasibility, accessibility, scalability and sustainability. Practices in Quadrants B, D, and E are not successfully used because either their adoption potential or their relative contribution to expanded use of mineral fertilisers in Africa is limited. Many current soil fertility management options fall within Quadrant B and a challenge before ISFM is to move these options into Quadrant A by overcoming their shortcomings in terms of nutrient supply and use efficiency.

The potential for both up-scaling, through various institutions dealing with soil fertility management, and out-scaling by reaching more farmers, greatly assists in better targeting future investment in ISFM.

Currently, the level of success of these practices is modest, for a number of reasons:

1. livelihood strategies are influenced by many other factors besides ISFM, making ISFM-specific success less visible,
2. developments in breeding have a stronger 'breakthrough' character because dissemination is more rapidly available and visible,
3. successes in ISFM are hard to come by because the Structural Adjustment Programs made fertiliser use unattractive to many farmers for several years, and
4. research and development efforts in the past lacked clear and consistent monitoring and evaluation tools to assess soil management capabilities.

Success must be expressed by impact indicators, such as yield increases, increased fertiliser sales, increased agronomic efficiency, and/or numbers of ISFM adopters.

The ISFM case in Figure 3 is useful in formulating strategies for intervention and direct future investment. The basic criteria for investments are: (i) proven successes because the farming system or technology has convincing impact and is ready for up-scaling; and (ii) likely successes where the farming system or technology may not have yet proved successful but is currently considered to be 'higher potential' because of soaring local, regional and world demand for agricultural products. One of the greatest strengths of ISFM is its capacity to integrate local suitability, economic returns/profitability, adoptability, and sustainability in developing improved land management recommendations.

While the goal of ISFM, to deliver nutrients to crops in a resource-, labour- and cost-effective manner, remains constant, the means to achieve ISFM varies within different agro-economic zones and cropping systems. Successful and potentially successful case studies mentioned above are located in different agro-ecological zones, which have different inherent soil-related constraints that need

Table 2. Selected characteristics of selected agro-ecological zones in sub-Saharan Africa (FAO 1995; FAO/IIASA 2000; FAO/IIASA 2002). Lowland, <800 m above sea level (masl); mid-altitude, 800–1200 masl; highland, >1200 masl. Growing periods are <150 days in dry areas, 150–270 days in savannas and >270 days in forest areas.

Agro-ecozone (% of the area)	Appropriate ISFM technologies	Major soil orders (FAO system)	Major nutrient-related constraints
Lowland dry savanna (36%)	Microdosing, Agro-pastoral interactions, Rock phosphate	Arenosols, Lithosols, Regosols	Low available soil P; soil acidity; low water holding capacity
Lowland moist savanna (17%)	Cereal–legume rotation and intercrops; Conservation agriculture	Lixisols, Ferralsols	S, Zn deficiency under intensive cultivation; low available N and P
Lowland humid forest (15%)	Cassava–legume intercrops, understorey & lowland rice management	Ferralsols, Arenosols	Soil acidity; low available soil P
Mid-altitude moist savanna (7%)	Cereal–legume rotation and intercrops; Conservation agriculture, slope management	Ferralsols, Arenosols	Soil acidity; low available N and P
Highland moist savanna (7%)	Intercrops and rotations, slope management	Ferralsols, Arenosols	Soil acidity; low available soil P

to be addressed, as outlined in the following sections and Table 2. Additional information on some of these zones is presented in Figure 4.

A broad and flexible approach to strengthening ISFM is envisaged which can result in large-scale impact in a relatively short time in the major intensification or impact zones in SSA. Improving and disseminating ISFM in drylands through improved fertiliser placement, manure management and water harvesting is key within the Sahel, an area characterised by extreme poverty and episodic famine. Enhanced use of fertiliser within cereal croplands, accompanied by deriving maximum benefit from nitrogen-fixing legumes grown as intercrops or in rotation, is an entry point for achieving food security and income generation in moist savannas and dry woodlands of eastern, southern and western Africa. Proven land management practices and, to a lesser extent, appropriate soil fertility products, are well established within these two agro-ecological zones of Africa, and it is only the lack of strategic planning and market development resources that impedes their widespread adoption.

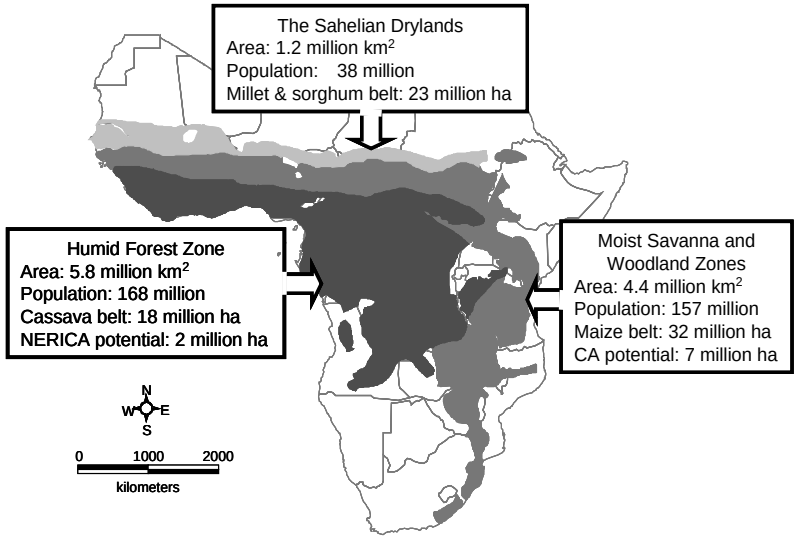


Figure 4. A summary of the characteristics of the zones and cropping systems warranting investment in ISFM.

ISFM guidelines are less developed within three areas: (i) the humid lowlands of Central and West Africa where root crops and banana are staple crops, (ii) within upland rice systems in conjunction with the growing importance of the New Rice for Africa (NERICA), and (iii) in conservation agriculture where soil quality improves with time but innovative uses of farm inputs are required.

Three accompanying developments are also necessary for the benefits of ISFM to become realised:

- improved capacity in the diagnosis and response to soil fertility constraints,
- greater access to farm input and commodity markets by small-scale farmers, and
- strategic policy adjustments that stimulate institutional and market response toward ISFM and its resulting crop surpluses.

All the above cannot be realised without reviving and strengthening human and financial resources.

There are constraints to improved targeting of recommendations on soil fertility inputs in SSA. They include:

- the use of over-generalised blanket recommendations that do not take into consideration farmers' diverse socio-economic and biophysical conditions,
- poor soil and crop management by farmers,
- lack of sufficient knowledge,
- limited access to responsive varieties,
- low and variable rainfall,
- limited access to stable produce-markets,
- limited financial means and access to credit.

If we assume for the moment that the degrees and types of nutrient limitations are recognised, and that technologies to ameliorate those conditions are identified, then the next important step is to devise strategies that facilitate the delivery of these technologies to needy farmers. These technologies must be 'packaged' into products and field operations that are recognisable, available and affordable to farm households. Clearly, policy interventions and marketing strategies can improve farmers' access to improved technologies but these will remain under-utilised if they appear over-priced or are perceived as risky. The following points, in the next section, relate to the understanding and promotion of ISFM technologies among farmers at the grassroots level.

Fertiliser as an entry point for ISFM

The recommendation of the Fertiliser Summit, 'to increase the fertiliser use from the current 8 to 50 kg nutrients/ha by 2015', reinforces the role of fertiliser as a key entry point for increasing crop productivity and attaining food security and rural well-being in SSA.

The impact of this target will, however, vary depending upon the agronomic efficiency of fertiliser, defined as 'the amount of output (such as crop yield) obtained per unit of fertiliser applied'. This rate varies across regions, countries, farms and fields within farms, and greatly affects the returns to the recommended 50 kg/ha (Prudencio 1993). Generally on responsive soils, where the applied fertiliser nutrients overcome crop nutrient limitations, substantial responses to fertiliser can be expected (Vanlauwe et al. 2006). On soils where other constraints are limiting crop growth (less-responsive soils), fertilisers alone in absence of other corrective measures result in relatively low agronomic efficiencies and small improvement in crop yield (Carsky et al. 1998; Zingore et al. 2007a,b).

Also important is the heterogeneity that exists between households within a community, translated in differing production objectives and resource endowments (Tittonell et al. 2005a,b; Giller et al. 2006).

The above factors co-determine the range of soil fertility management options available to the household. Ojiem et al. (2006) derived the concept of the 'socio-ecological niche' for targeting ISFM technologies, which must be embedded into local social, economic and agro-ecological conditions.

Fertiliser not only improves crop yields but it also increases the quantity of available crop residues useful as livestock feed or organic inputs to the soil (Bationo et al. 2004). Targeting phosphorus (P) application to legumes doubles crop biomass and increases the fertiliser agronomic efficiency of the next cereal crop (Vanlauwe et al. 2003; Giller et al. 1998). Similarly, strategic application of nitrogen (N) fertiliser improves the performance of most cropping systems, even N-fixing legumes. For example, application of small amounts of starter N to legumes stimulates root growth, leading to better nodulation and increasing the N contribution to a succeeding cereal crop (Giller 2001; Sanginga et al. 2001). More accurate timing and placement of top-dressed N during peak demand of maize greatly improves crop yield and agronomic efficiency (Woomer et al. 2004, 2005).

Mineral fertilisers are important within ISFM, but not as a stand-alone means to crop nutrient management. Within responsive soils, fertiliser is indeed a valid entry point for ISFM, while in the poorest soils organic resource management options must be implemented in conjunction with mineral fertiliser addition before sufficient crop responses are realised. This situation holds true under a number of soil conditions, including shallow sandy soils, degraded soils with collapsed physical structure and low soil organic matter, and highly weathered soils with toxic properties.

Fertiliser quality is often problematic. Manufacturers and blenders commonly lack the essential agronomic information to formulate appropriate nutrient compositions in fertilisers. Crop nutrient requirements depend on the environment, and change with time and intensifying crop production. Obtaining this information is hampered by ineffective linkages with experimental stations and lack of regular crop surveying. Loss of fertiliser quality through poor storage and adulteration, occurring mostly during repackaging, is another constraint and it greatly discourages farmer investments in fertiliser.

A major problem for effective utilisation of fertilisers and ISFM practices in Africa has been inability to deliver appropriate recommendations and accompanying inputs in the right form to smallholder farmers. Past fertiliser recommendations have been based on single major cash crops such as maize, tea and cotton, delivered in 'pan-territorial/blanket' form, failing to take into account the spatial variation in smallholders' resource endowment (soil type and condition, labour capacity, climate risk, etc.). There is need therefore to move away from 'blanket' recommendations and instead base guidelines for fertiliser use on the principles of ISFM, targeting dissemination programs to the specific crop production problems faced by farmers and their socio-economic circumstances and production goals.

Many fertiliser recommendations made to farmers are regarded as excessive, and rightly so. Fertiliser recommendations are generally based upon sound field trials, but too often they are formulated by optimising returns per unit area rather than per unit input. Gain per unit area is appropriate information for commercial production, but this approach is inappropriate to more limited investments in fertiliser by cash-poor farmers. These farmers are better positioned by maximising their returns per unit input (Figure 5). Recommended fertiliser rates based upon the greatest returns per unit input are usually 30% to 50% of those based upon unit area. This implies that if a farmer can afford to fertilise only one-third of the farm at the recommended rate per unit area, then she is better off by applying only one-third of that rate to the entire farm.

Nonetheless, it is critical that fertiliser recommendations be re-examined within this context and adjusted downward to levels better afforded by small-scale farmers. Different fertilisers may be managed in different ways particularly within the context of ISFM. Furthermore, fertiliser recommendations are only starting points in fine tuning a land manager's nutrient management strategy. More localised fertiliser recommendations are best developed, adjusted and validated through close collaboration between researchers, extension agents

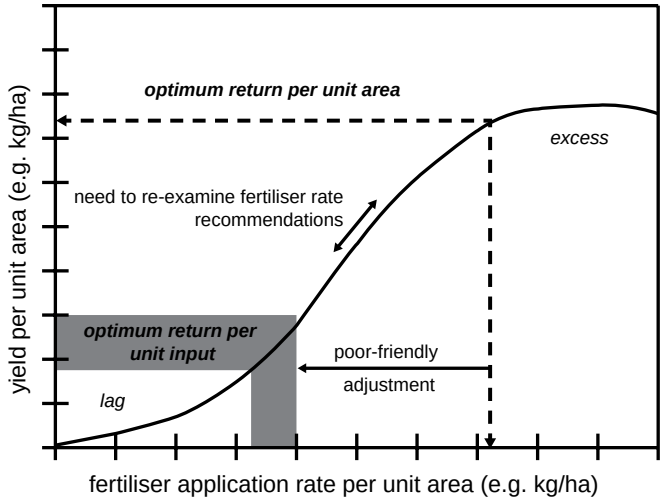


Figure 5. Fertiliser recommendations formulated for small-scale farmers should be based not upon maximizing return per unit area, as is customary, but rather optimizing return per unit fertiliser input.

and farms. Farmers must be empowered to undertake adaptive adjustments to local recommendations that meet the requirements of their individual farms and fields.

Several steps are required before fertilisers of the correct type are sufficiently available to smallholder farmers in Africa and become adopted within the context of ISFM. First, better diagnosis of soil and plant constraints by rural planners must be achieved so that the correct types and blends of fertilisers become marketed. Then the use of these fertilisers must become nested within ISFM recommendations targeted to a farmer's agro-ecological setting, production strategy and socio-economic conditions. To achieve this goal, human and institutional capacities must be directed towards finding integrated solutions to soil constraints that make best use of farmers' limited resources, and that balance the benefits of redirecting cash investment and labour.

Key considerations in devising ISFM strategies

Fertiliser advice must not only provide suggested types and rates but also offer guidelines on how to make adjustments in conjunction with the use of commonly available organic resources. For example, manure piles that are protected against nutrient loss need smaller amounts of mineral fertilisers to supplement them.

ISFM approaches may follow two parallel paths, one for strictly commercial production that optimises returns per unit area and another intended for resource-poor farmers that makes best use of limited fertiliser. Different resource endowment categories exist within a given farming community and the capacity of each category to invest in mineral fertilisers differs. Similarly,

households have different degrees of labour availability. Farmers producing cereals for markets should be offered one set of recommendations, and those who are seeking food security for the least cost could be offered another set where less fertiliser is used more efficiently.

Different ISFM recommendations can be forwarded for soil fertility niches within farms and for major topographies. Spatial heterogeneity within and across farms results from topography, nutrient and soil gradients and specialised niches, and these differences necessarily influence nutrient management. In many cases heterogeneity has been intensified during past management when, say, more resources may have been devoted to nearer or more productive fields. Separate practices are required for severely degraded and nutrient-depleted lands to allow farmers to rehabilitate their least productive fields in a resource- and time-efficient manner.

Localised fertiliser recommendations are best developed, adjusted and validated through close collaboration between researchers, extension agents, farmer associations and their members. Participatory research methods can guarantee farmers have a role in the formulation of recommendations, and reveal farmers' adaptive and adoptive responses to those recommendations and the impacts resulting from them. This approach is markedly different from top-down prescriptive approaches to fertiliser use where farmers themselves need to adjust recommended management practices to suit their farming conditions and household priority setting. However, the level of participation can vary, depending on the complexity of the knowledge underlying a specific intervention.

The craft of ISFM involves making the best use of affordable fertilisers, available organic resources and accessible agro-minerals. Better management of fertiliser calls for farmers to gain increased knowledge through information and training campaigns. Corresponding actions include promotion of fertiliser micro-dosing, water conservation, management of soil organic matter, better integration of legumes into farm enterprises and mobilisation of available agro-minerals. Lack of farmer knowledge on production, conservation and effective utilisation of organic resources is a major constraint and it needs to be addressed through information directed through a variety of sources.

Guidelines in ISFM practice cover generalised practices for different sorts of fertilisers, and more specialised approaches for specific categories of land and household resources. As recommendations become more localised, greater knowledge of ISFM is required. Ultimately, it is the responsibility of individual farmers as ISFM practitioners to make adjustments to local recommendations based upon their specific conditions. Examples of ISFM guidelines follow.

Combine the strategic application of fertilisers and farmer-available organic resources in a manner that increases nutrient use efficiency and makes fertiliser use more profitable

In West Africa, for example, farmers have adopted the 'microdose' technology that involves strategic application of small doses of fertiliser (4 kg P/ha) and seed (Tabo et al. 2006). This rate of fertiliser application is only one-third of the

recommended rate for the area. As a result of adoption of 'microdoses', grain yields of millet and sorghum were increased by between 43% and 120% in all the project study sites in Burkina Faso, Mali and Niger. The incomes of farmers using this practice increased by 52–134%. Small amounts of fertilisers are more affordable for farmers, give an economically optimum (though not technically maximum) response, and, if placed in the root zone of these widely-spaced crops rather than uniformly distributed, result in more efficient uptake (Bationo & Buerkert 2001). In addition, the number of farmers using fertilisers in the study sites dramatically increased. The successful experience has shown that adoption of microdose technology requires supportive and complementary institutional innovation and market linkage such as 'warrantage'.

Optimise improved germplasm, water use efficiency and agronomic practices within new soil fertility input recommendations

Studies have shown that introduction of a cash crop, such as cowpea or soybean or high value vegetables, into the cropping system can greatly boost the use of fertiliser by smallholder farmers and increase yields of succeeding food crops. The importance of crop diversification was emphasised at the Oslo Conference on the African Green Revolution, where it was noted that crop diversification can help in optimising farmer returns and, as a principle of risk management, protect those returns. Similarly new crop varieties have been bred recently for drought tolerance and adaptation to low soil fertility, and there is need to increase their adoption by smallholder farmers.

Keep recommendations and demonstrations simple

On-farm trials and community demonstrations that are designed by agricultural scientists are too often overly complex and this distracts farmers from their intended message. Integrated Soil Fertility Management is complex and knowledge-intensive and special attention must be placed upon capturing its findings into simplified field operations. Researchers who install large, replicated, randomised experiments in farmers' fields that are intended to host instructional field days risk confusing their clients. More information and better feedback is conveyed from simpler on-farm field demonstrations and technology trials.

Work through existing organisations and networks

Working with existing farmer associations and their umbrella networks to promote fertiliser use offers several advantages. To a large extent, these farmer groups formed as a means of better accessing information and technologies in the absence of adequate support from agricultural extension. These groups represent a ready formed audience for technical messages, which will collectively undertake independent evaluation of technologies and provide necessary feedback on them. Larger organisations offer farm input supply services to their members, allowing them to purchase fertilisers in bulk or on credit, and pass savings onto members. Farmer groups provide peer support to members, allowing them to undertake new and more complex field operations and investments. Other stakeholders, particularly farm input suppliers, also deserve attention during the planned promotion of fertilisers, but groups of potential fertiliser users must not be overlooked.

Adhere to market-led and value chain addition paradigms

The Market-Led Integration Hypothesis states that 'improved profitability and access to market will motivate farmers to invest in new technology, particularly the integration of new varieties with improved soil management options'. It is based in part upon the disappointing past experiences of developing and promoting seemingly appropriate food production technologies, only to have them rejected by poor, risk-averse farmers unable or unwilling to invest in additional inputs. This simple hypothesis captures a unifying breakthrough. When working in the market-led mode, agronomists will no longer assume that additional produce resulting from technical adoption, including the expanded use of fertilisers, will necessarily benefit the household; nor will economists assume that demand created through market innovations will automatically be filled. Value chain addition examines farm planning, field operations and produce-marketing, in a holistic context that permits the innovations necessary to improve farming enterprises, including a farmer's investment in fertiliser, to be more readily identified and compared.

A way forward

The future of small-scale farming households largely rests in their ability to rapidly seize new production and marketing opportunities, and corresponding actions by national planners and development agencies to better empower farmers' collective action.

Hindrances beyond smallholders' control persist: notably weak networks of rural roads and utilities which in turn result in high costs both of farm inputs and of marketable crop surpluses. Agricultural extension is sporadic at best and attempts at extension reform are largely ineffective. Much of this dilemma is related to improperly translated 'training and visitation' extension models because of the large numbers of extension clients resulting from increasingly small farms. Even the frontline extension agents presently in place lack sufficient educational materials and financial resources to assist their nearest clients (Lynam & Blackie 1994).

Recent reviews of the different stakeholders and partners involved in ISFM research for development in SSA point to the need to build capacity and to consolidate efforts at all levels — from farmers to researchers and policy makers.

To generate and deliver demand-driven knowledge and technologies, there is a need for a platform on ISFM supported by a Center of Excellence in SSA, to foster partnerships between advanced research institutions, national agricultural research and extension systems, and the private sector. The platform will support capacity-building and drive the generation of new knowledge and approaches to disseminate ISFM practices. Different mechanisms will be used, including consortia, and networks such as the African Network for Tropical Soil Biology and Fertility (AfNet) — a pan-African network that is able to mobilise 400 scientists who engage in ISFM research for development.

Funding for ISFM research needs to recognise the urgency for immediate action and for longer-term investment. At the heart of that support is a critical mass and diversity of soil scientists in SSA.

The platform will provide that mass, centred on the staffing of current institutions working on ISFM in SSA. In addition, laboratory facilities are urgently needed for the type of research described above. There is thus a crucial need for a targeted and committed investment in ISFM, in SSA and more widely, to enable and enhance the momentum that has already been achieved by the Bill and Melinda Gates Foundation, the Rockefeller Foundation and their partners.

Conclusion

In summary, ISFM aims at effective use of inputs by combining a number of components. ISFM practices involve:

1. judicious use of mineral fertiliser and agro-minerals, in terms of their form, placement and timing of application;
2. management of crop residues and other locally-available organic resources in a way that improves agronomic efficiency;
3. use of locally adapted germplasm that is resistant to local stresses and conditions, both biotic and abiotic; and
4. other field practices determined by local agricultural conditions, particularly pest and disease management, soil erosion control, moisture conservation and the enhancement of beneficial soil biota.

These considerations lead to a suite of field practices based upon past experience, current information and changing farming conditions. They will result in better soil fertility management — an essential component of rural development in Africa.

References

Bationo A. & Buerkert A. (2001). Soil organic carbon management for sustainable land use in sudano-sahelian West-Africa. *Nutrient Cycling in Agroecosystems* 61: 131–142.

Bationo A., Kimetu J., Ikerra S., Kimani S., Mugenda D., Odendo M., Silver M., Swift M.J. & Sanginga N. (2004). The African Network for Soil Biology and Fertility (AFNet): New challenges and opportunities. In: Bationo A. (Ed.) *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*. Academy Science Publishers, Nairobi, Kenya. pp. 1–23.

Bationo A., Waswa B., Kihara J. & Kimetu J. (2006). Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities. *Nutrient Cycling in Agroecosystems* 76.

Buresh R.J., Sanchez P.A. & Calhoun F. (1997). *Replenishing Soil Fertility in Africa*. Soil Science Society of America Special Publication No 51. Madison, USA. 251 pages.

Carsky R., Jagtap S.S., Tian G., Sanginga N. & Vanlauwe B. (1998). Maintenance of soil organic matter and N supply in the moist savanna zone of West Africa. In: Lal R. (Ed.) *Soil Quality and Agricultural Sustainability*. Ann Arbor Press, Michigan, USA. pp. 223–236.

FAO (1995). *Fertilizer and Plant Nutrition Bulletin No. 12*. Food and Agriculture Organization of the United Nations, Rome.

FAO/IIASA (2000). Global agroecological zones 2000. Online database at http://www.Fao.org/ag/agl/Agll/Gaez/Index.htm. Food and Agriculture Organization of the United Nations, and International Institute for Applied Systems Analysis.

FAO/IIASA (2002). *Global Agroecological Assessment for Agriculture in the 21st Century*. International Institute for Applied Systems Analysis, Luxembourg.

Giller K.E. (2001). *Nitrogen Fixation in Tropical Cropping Systems*. Second Edition. Wallingford, UK: CAB International.

Giller K.E., Gilbert R., Mugwira L.M., Muza L., Patel B.K. & Waddington S. (1998). Practical approaches to soil organic matter management for smallholder maize production in Southern Africa. In: Waddington S.R., Murwira H.K., Kumwenda J.D.T, Hikwa D. & Tagwira F. (Eds) *Soil Fertility Research for Maize-based Farming Systems in Malawi and Zimbabwe*. Soil Fertility Network and CIMMYT, Harare, Zimbabwe, pp. 139–153.

Giller K.E., Rowe E., De Ridder N. & Van Keulen H. (2006). Resource use dynamics and interactions in the tropics: Scaling up in space and time. *Agricultural Systems* 88: 8–27.

Lynam J.K. & Blackie M.J. (1994). Building effective agricultural research capacity: The African challenge. In: Anderson J.R. (Ed.) *Agricultural Technology: Policy Issues for the International Community*. Wallingford, UK: CAB International, pp. 106–134.

Ojiem J.O., De Ridder N., Vanlauwe B. & Giller K.E. (2006). Socioecological niche: A conceptual framework for integration of legumes in smallholder farming systems. *International Journal of Agricultural Sustainability* 4: 79–93.

Prudencio C.F. (1993). Ring management of soils and crops in the West African semi-arid tropics: The case of the Mossi farming system in Burkina Faso. Agriculture *Ecosystems and Environment* 47: 237–264.

Sanchez P.A. (1994). Tropical soil fertility research toward the second paradigm. *15th World Congress of Soil Science*. Acapulco, Mexico, pp. 65–88.

Sanchez P.A., Shepherd K.D., Soule M.J., Place F.M., Buresh R.J., Izac A-M.N., Mokwunye A.U., Kwesiga F.R., Ndiritu C.G. & Woomer P.L. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh R.J., Sanchez P.A. & Calhoun F. (Eds) *Replenishing Soil Fertility in Africa*. Soil Science Society of America & American Society of Agronomy. SSSA Publication No. 51.

Sanginga N., Okogun J.A., Vanlauwe B., Diels J. & Dashiell K. (2001). Contribution of nitrogen fixation to the maintenance of soil fertility with emphasis on promiscuous soybean-based cropping systems in the moist savanna of West Africa. In: Tian G. Ishida F. & Keatinge J.D.H. (Eds). *Sustaining Soil Fertility in West Africa*. SSSA Special Publication No. 58. Soil Science Society of America. Madison, USA. pp. 157–178.

Tabo R., Bationo A., Gerald B., Ndjeunga J., Marchal D., Amadou B., Annou M.G., Sogodogo D., Taonda J.B.S., Hassane O., Diallo M.K. & Koala S. (2006). Improving cereal productivity and farmers' income using a strategic application of fertilizers in West Africa. In: Bationo A., Waswa B.S., Kihara J. & Kimetu J. (Eds). *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Springer, Netherlands, pp. 201–208.

Tittonell P., Vanlauwe B., Leffelaar P.A., Rowe E. & Giller K.E. (2005a). Exploring diversity in soil fertility management of smallholder farms in Western Kenya. I. Heterogeneity at region and farm scale. *Agriculture Ecosystems and Environment* 110: 149–165.

Tittonell P., Vanlauwe B., Leffelaar P.A., Shepherd K.D. & Giller KE. (2005b). Exploring diversity in soil fertility management of smallholder farms in Western Kenya. II. Within farm variability in resource allocation, nutrient flows and soil fertility status. *Agriculture Ecosystems and Environment* 110: 166–184.

Vanlauwe B., Aihou K., Aman S., Iwuafor E.N.O., Tossah B.K., Diels J., Sanginga N., Merckx R. & Deckers S. (2001). Maize yield as affected by organic inputs and urea in the West African moist savanna. *Agronomy Journal* 93: 1191–1199.

Vanlauwe B., Bationo A., Carsky R.J., Diels J., Sanginga N. & Schulz S. (2003). Enhancing the contribution of legumes and biological nitrogen fixation in cropping systems: Experiences from West Africa. *Grain Legumes and Green Manures of Soil Fertility in Southern Africa: Taking Stock of Progress.* Proceedings of Soil Fertility Network Meeting, Vumba, Zimbabwe, pp. 3–13.

Vanlauwe B., Tittonell P. & Mukulama J. (2006). Within-farm soil fertility gradients affect response of maize to fertiliser application in Western Kenya. *Nutrient Cycling in Agroforestry* 76: 171–182.

Woomer P.L., Lan'gat M. & Tungani J.O. (2004). Innovative maize–legume intercropping results in above and below ground competitive advantages for under storey legumes. *West African Journal of Applied Ecology* 6: 85–94.

Woomer P.L., Tungani J., Odhiambo G. & Mwaura F.M. (2005). Striga management options in Western Kenya. *African Crop Science Conference Proceedings* 7: 479–484.

Zingore S., Murwira H.K., Delve R.J. & Giller K.E. (2007a). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. *Agriculture Ecosystems and Environment* 119: 112–126.

Zingore S., Murwira H.K., Delve R.J. & Giller K.E. (2007b). Soil type, historical management and current resource allocation: Three dimensions regulating variability of maize yields and nutrient use efficiencies on African smallholder farms. *Field Crops Research* 101: 296–305.

Dr Nteranya Sanginga assumed the leadership of the International Institute of Tropical Agriculture in November 2011. He has a wealth of experience in agricultural research and development, particularly in applied microbial ecology, plant nutrition, and integrated natural resources management in Africa, Latin America, and South-East Asia. He was the Director of CIAT-TBSF and worked at the University of Zimbabwe, IAEA, and IITA where he served as principal scientist, head (soil microbiology unit), project coordinator, and program leader. He has trained more than 30 PhD candidates, who are now leaders in their countries. Dr Sanginga, from Democratic Republic of Congo (DRC), did his postgraduate training at IITA and PhD in Agronomy/ Soil Microbiology under a joint program with partners in DRC, Burundi, and Rwanda.

Email: N.Sanginga@cgiar.org

Helping farmers innovate to harvest more from less

Dr Trevor Nicholls
CAB International

Abstract

By 2050, we face the challenge of feeding 50% more people within the finite and diminishing resources on the planet. Significant investment is going into the development of new crop varieties that will offer higher yields, greater pest resistance or better tolerance of adverse conditions. There is also a vigorous debate about the potential to extend available farmland and increase the global area under cultivation. These developments can be only part of the solution. Agriculture will face increasing competition for scarce water and land resources as society seeks to balance its needs and desires for more food with demands for increasingly scarce (and hence lucrative) mineral resources, space for urbanisation, protection of ecosystems and protection of biodiversity. Simply expanding agricultural capacity will not be sufficient. We must lose less of what we already grow and use existing inputs more efficiently if we are to meet the challenge of achieving global food security. On average, 40% of the crops grown worldwide are lost to pests and diseases before they reach the consumer, on top of which is wastage during processing, spoilage at retailers and over-purchasing by consumers. This paper considers how innovations in pest management, water usage, fertiliser technology and soil health improvement can help us feed more people. To be effective, new technologies or techniques must be communicated to and adopted by farming communities around the world for innovation and uptake to take place. In the face of a chronic shortage of funding, skills and resources to support extension systems worldwide, this paper also looks at how new approaches and technologies can be used to get relevant actionable information to rural smallholders.

The problem

The challenges of feeding a growing world population have been well documented in many press articles and position papers. To feed a global population projected to grow from 7 billion now to 9 billion by 2050, the world's agricultural productivity must increase in the next 40 years by as much as it has in the previous 12,000 years. That growth must be achieved in the face of a perfect storm of other factors such as rising energy prices, dwindling mineral resources, shortage of water and, of course, climate change.

Simply increasing the area of land we cultivate is no longer an easy option, with growing demands to use land for housing (urban and rural), mining, water storage, recreation or the preservation of biodiversity. Paradoxically,

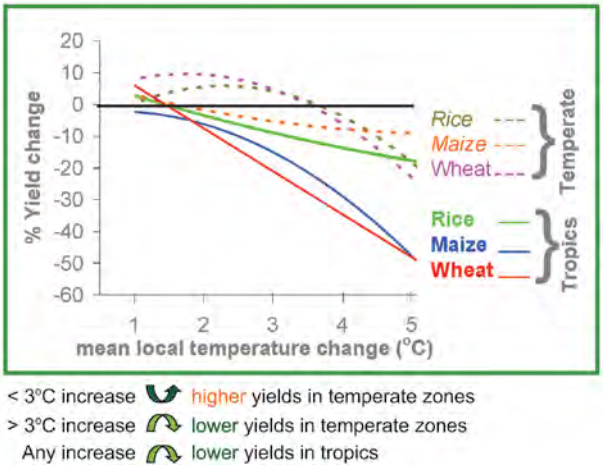


Figure 1. With higher temperatures yields are generally expected to be lower. (Adapted by Norgrove from IPCC (2007) based on 69 studies.)

as development initiatives succeed and living conditions improve, the task gets harder. Increasing incomes around the world increase the demand for meat and dairy products, requiring larger inputs of fodder and water per calorie or kilogram of nutrient produced, as well as increasing the overall greenhouse gas emissions from farming.

The debate today is often focused on cereal crops — rice, maize, wheat. These are vitally important in terms of food security and they are naturally the focus of a lot of our breeding efforts. However, we also need to think about vegetables, about fruit, and about cash crops such as cocoa and coffee that provide essential dietary nutrients and variety or valuable income for smallholder households, particularly in the tropics.

Nor are we operating on a level 'playing field'. Many of the cereal crops that are grown today have been optimised for the temperatures and climatic conditions of 10 or 20 years ago. If temperatures actually rise by the amounts predicted by some of the climate change models, then many of the varieties in use today will no longer be growing within their optimum temperature ranges. Yields from current cultivars of rice, wheat and maize could decline significantly, particularly in the tropics (Figure 1).

New varieties are critical in helping meet those challenges, and the potential for developing traits with resilience in a harsher climate is now much greater as a result of advances in both conventional and biotech breeding approaches. Therefore, despite an apparently gloomy prognosis, I remain optimistic that we can find and, more importantly, implement new ways of working to address these challenges.

This paper reviews some of the potential solutions offered by technology and then considers new opportunities that modern communication technologies provide for creating awareness and uptake among smallholder farmers. It considers some of the broader mechanisms that must be put in place to really enable and drive that change. The focus is on helping make farming a profitable and attractive rural profession, not just a last resort for scratching out a living.

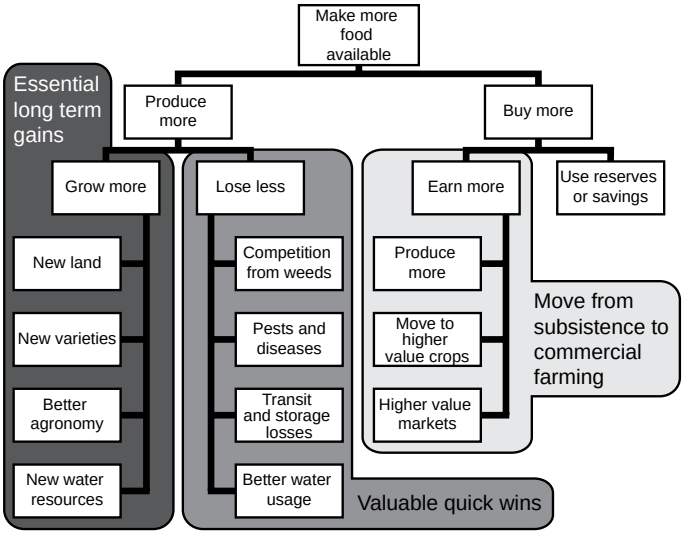


Figure 2. Food security can come through building or buying.

Will technology help us find the solutions?

In looking to achieve food security at household, community or national level we can seek to either produce more food or to buy more.

In relation to producing more, there are two sides to the equation: to grow more, and to lose less (Figure 2). By helping farmers earn more we can also enable them to buy a better variety of diet and make them more resilient to price and supply shocks. The focus of most research and technology development effort is to find ways to grow more, and this will be essential to meet the challenge. Unfortunately, the time period for introduction of a new variety is typically 10–15 years so that these gains will be in the longer term.

However, we can gain some valuable quick wins by focusing effort on the 'lose less' side of the equation. It is a shocking fact that, on average, 40% of what is already grown is lost — to pests, weeds and diseases — yet we already have much of the knowledge needed to reduce these losses. Therefore, a focus on losing less could give us some valuable quick successes in the war on hunger.

As an example of the potential for yield improvement through knowledge and technology available today, consider the Philippines. It is both a major rice-growing country and a significant importer to meet domestic consumption needs. Current domestic production in 2010 was 15.8 Mt and this was augmented by imports of 1 Mt to meet total consumption of 16.8 Mt (Philippines Department of Agriculture). However, it is estimated that total losses because of pests, diseases and supply-chain wastage amount to 4.8 Mt per year. The International Rice Research Institute (IRRI) also estimates that adoption of the most suitable hybrid varieties could increase yields by 10%. So, in theory, by halving its losses and adopting hybrids the Philippines could increase rice output by approximately 4 Mt, giving it the potential to become a net exporter of up to 3 Mt of rice per annum.

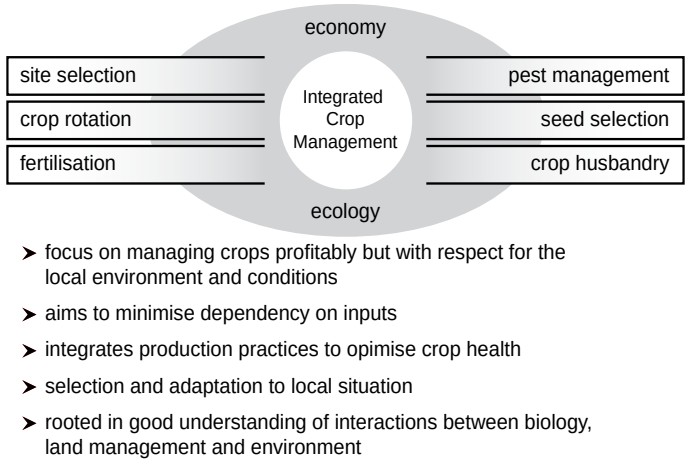


Figure 3. Integrated crop management relies on good understanding of interactions between crop biology, pest ecology, land management and the landscape.

Modern biotechnology promises potential benefits for the future, such as greater tolerance of heat and water stresses, resistance to pests, resilience to saline conditions or even the fundamental re-engineering of nutrient content, nitrogen fixation and photosynthetic efficiency in some crops. Many of these developments are not dependent upon genetic engineering and so will not get delayed by the debate over public acceptance of genetically modified organisms. Recent rapid advances in the sequencing of plant genomes, and the reduction in the cost of such techniques, now make it possible to accelerate the introduction of desirable characteristics through traditional plant breeding techniques that have been used for hundreds of years. Instead of making crosses and patiently waiting to see if the resulting plants have the desired traits when they are grown in the field, we can now identify the genes responsible for the desired traits and use molecular markers to check whether they have been brought together in the breeding process. Work by the World Vegetable Centre (AVRDC) on plants such as tomato and eggplant has already shown that many of the desired characteristics of stress tolerance, nutritional quality, flavour and appearance can be achieved through such breeding approaches.

In seeking to reduce crop losses, it is essential to take a systematic approach, not just focusing on the crop itself but also taking into account the soil conditions, environment, pests and weeds around that crop, as well as site selection, crop husbandry, storage and transport to market (Figure 3). Integrated crop management practices must be rooted in a good understanding of interactions between crop biology, pest ecology, land management and the broader landscape to ensure that agricultural practices are sustainable and serve as a foundation for future generations.

CABI is one of nine organisations forming the Association of Independent Research and Development Centers for Agriculture (AIRCA) which seeks to develop and promulgate support of healthy landscapes through an innovative

systematic approach to agricultural development. The approach balances the imperative to lift yields and outputs against the need to secure the sustainability of the environment within which that production takes place. AIRCA will address the challenge of increasing global food security by identifying and disseminating science-based development solutions to problems met in smallholder agriculture within the context of healthy, sustainable and climate-smart landscapes.

In much of Africa and Asia there are large gaps between actual and optimum yields for most crops. In closing these gaps, we need to value and use water as a precious resource. Agriculture is the biggest, and probably most wasteful, user of water worldwide; it is imperative to get more crop per drop. With basic good practice and simple technology it is already possible to achieve usage savings of anywhere from 15% up to as much as 50%. At its simplest, this just requires better management of available resources through fixing leaks, improving drainage and irrigation systems, storing available rainfall and using greywater where appropriate. Techniques of mulching or alternate wetting and drying (for rice) significantly reduce evaporative losses and water usage whilst the adoption of drought tolerant varieties can make the farming system more resilient to water shortages. For a relatively low capital outlay (perhaps supported through development grants or micro-finance) farmers can invest in drip irrigation systems to use water more efficiently and reduce the problems of salinisation that can arise from over-watering. In more commercial farming environments water accounting and pricing systems can give farmers an incentive to minimise water usage, and telemetry and precision agriculture techniques can help them apply just the right amount of water, in the right place at the right time.

Soil health is also a major problem in much of Africa and South Asia, where practices designed to maximise output have mined the soil of available nutrients, created saline environments or degraded soil structure, leaving it prone to erosion. The benefits of low-till or zero-till strategies have been known for many years. Even though they have been widely demonstrated, uptake is still not widespread. Good agricultural practices of crop spacing, timing of planting, weed and pest management, as well as crop rotation are also relatively simple for farmers to implement once they have the necessary information (Figure 4). It is critical that this advice is carefully adapted to local conditions and crops for it to have impact.

These practices can also encourage farmers to use organic fertiliser inputs from manure, compost or legumes, because access to mineral fertilisers of good quality, at reasonable prices and in appropriate quantities is often a problem, particularly for smallholder farmers in Africa. In contrast, in some parts of Asia there is often over-usage of mineral fertilisers, leading to unnecessary costs for farmers, as well as unwanted run-off into streams and rivers. Organisations such as the International Fertilizer Development Center are encouraging advances in micro-dosing and formulation, as well as simple decision tools and guidelines, to help smallholder farmers use inorganic fertilisers more effectively and efficiently.

Losses to pests, weeds and diseases are major problems to farmers worldwide. Furthermore, climate change, trade flows, travel and population movements are

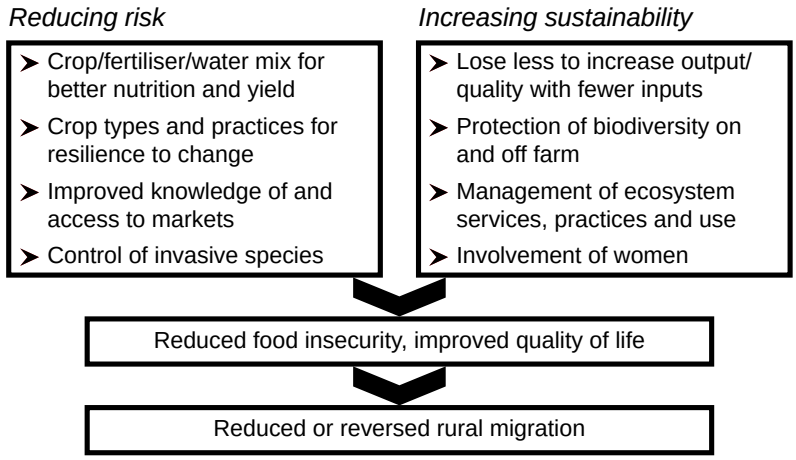


Figure 4. Healthy landscapes help make rural communities more viable.

increasing the rate at which new problems arise and spread. The importance and nature of these acute problems vary between smallholder and production systems, and from year to year as well as within and between countries. Crop protection projects address a limited range of major plant health problems on a limited range of crops, yet livelihoods depend on complex agricultural systems, with a variety of crops and livestock. Often, farmers do not have easy access to diagnostic services to help them identify the problem they are seeing or to give appropriate advice on how to manage that problem. This can lead to farmers relying on advice from friends or input suppliers, which can result in application of inappropriate and expensive chemical treatments. In many cases, problems can be more effectively and sustainably dealt with through integrated pest management approaches to crop production and protection. Those approaches combine a range of management strategies and practices, particularly the use of cultural, biological and mechanical methods to grow healthy crops and minimise the use of pesticides.

How do we get technology adopted more effectively?

Many smallholder farmers in Asia and Africa generally have mixed cropping systems, spreading their risks, but broadening the range of knowledge and advice they need to grow each crop successfully. The advice has to be reliable: available when needed, accurate, appropriate and proportionate. Sources of potential advice include public and private extension providers, agricultural institutes and local agro-dealers. Information is more widely available than ever before, and yet advisory services are weak, with a fundamentally poor dialogue between farmers and those who aim to help them.

As described in the preceding section, many of the technologies we need to close yield gaps and reduce inputs of water, energy and chemicals are already developed and available. Despite this, many farmers in the developing world are not aware of these techniques or have not adopted them. If the food security

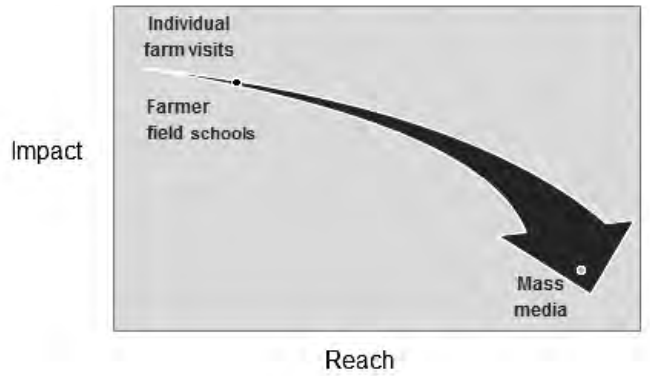


Figure 5. Farm visits can only reach a few farmers, and field schools also reach relatively few, but the farmers learn well; mass media reaches many farmers but teaches little.

challenges of the next 50 years are to be met, our highest priority has to be to improve resources, systems and methods of extension around the world in order to make better use of what we already know.

An inconsistent engagement with farmers also has several important longer-term consequences: slow awareness of new and emerging plant health problems; delayed responses in identifying the nature of the problems and giving suitable recommendations; systematic failure to learn from experiences; and inefficient use of existing sources of technical expertise. The net result is a failure to provide timely solutions that enable farmers to grow more food and earn more money.

Until recently, extension in the developing world either took the form of a face-to-face farm visit by an extension worker or relied on the use of mass media channels such as advertising in newspapers. The former has high impact but limited reach because the number of extension workers is small and farms may be far apart. Conversely, newspaper or radio campaigns can reach a large number of people but tend to be non-specific and have low impact (Figure 5).

Farmer field schools were developed as one way of reaching more farmers, but the approach and choice of crop or topic remains top-down and often does not address the most pressing problem faced by each individual farmer. Providing regular and reliable demand-driven advisory services requires innovative solutions that recognise the entrenched weaknesses in agricultural support systems, namely:

- there are not enough extension workers to reach all farmers;
- technical expertise is limited and difficult to access;
- the availability of inputs depends on supply chains that are erratic and dominated by agro-dealers.

There are also positives to build on, though these are often ignored:

- extension workers have a good knowledge of farmers and local conditions;

- technical experts want to work more closely with extension;
- agro-dealers want to respond to customers' needs and to be trusted.

CABI and others have been looking at ways to increase the reach of extension services whilst still maintaining the impact of their messages.

In Bangladesh, CABI has used community videos, made by the women of the villages themselves, to spread the word about best practices and new techniques for identifying quality seed, drying it and storing it for future harvests. As a result of the local relevance and credibility of these videos the awareness of proper seed management increased from 41% to 94% in the communities involved.

In Africa, with funding from the Bill and Melinda Gates Foundation, CABI has set up the African Soil Health Consortium as a communication mechanism to transfer knowledge on best practice in soil health to extension workers, agro-dealers and farmers.

In India, in a partnership with the leading mobile network operator (Airtel) and a major fertiliser supplier (IFFCO), CABI has supported a mobile agro-advisory network that now serves 4 million subscribing farmers. They receive up to five voicemail messages per day on a variety of relevant topics including weather, market information, pest alerts and crop management advice.

Plantwise

'Plantwise' is a major initiative, led by CABI with financial support from donors in the UK (DFID), Switzerland (SDC) and Australia (ACIAR), to bring better knowledge and advice to farmers for the identification and management of pests and diseases so as to reduce the losses and improve the quality of their crops. Plantwise is disseminating and gathering knowledge in two ways:

- locally, via a network of plant clinics in the developing world to help the poorest farmers, diagnosing plant health problems and giving them a 'prescription' for the problem; and
- globally, via a knowledge bank of data and information which supports the clinics but also aggregates and analyses their observations.

Plantwise clinics are set up at local meeting places, such as markets, village halls or agro-dealers, where farmers congregate in the normal course of their business. They provide a service that is either free at the point of use or has a small nominal charge. The clinics are run by local extension staff employed by the relevant national agencies so they use existing resources but enable extension workers to have high impact personal interactions with many more farmers. Plantwise has already trained over 1000 plant doctors who are now running 354 plant clinics in 24 countries. By 2016 CABI is aiming to expand coverage to over 40 countries and 1000 clinics.

For long-term sustainability, plant clinics need to be embedded in national systems and organisations of plant health, encompassing regulatory bodies, national plant protection organisations, advisory services, universities and agricultural research institutes. The Plantwise initiative also provides an innovative way to stimulate the partnerships needed to strengthen national plant health systems and to help them identify and manage plant health problems,

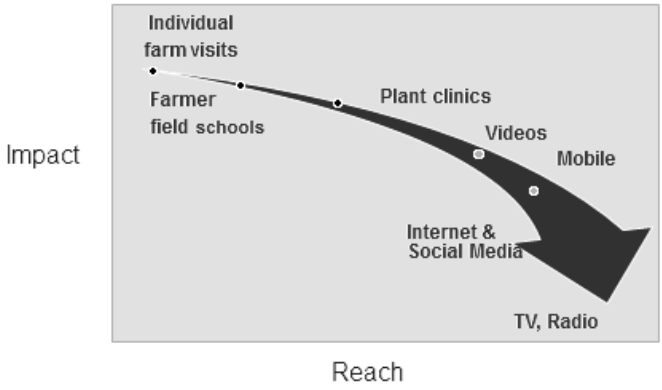


Figure 6. Modern communication technologies offer many ways of helping farmers learn.

including biotic and abiotic constraints. Plant clinics have many strategic advantages: they respond to and monitor shifting demands of farmers from year to year, by place and by production system. Yet plant clinics alone cannot solve all the problems that farmers face.

Plantwise has a knowledge bank that supports plant clinics and plant health systems by providing a platform for information sharing at national, regional and global levels. It provides open access to a wide range of information — from international scientific literature to simple actionable fact sheets in local language for use by extension staff and farmers. The database provides material that will be relevant at the level of the plant doctor or extension worker to enable them to help a farmer on the ground. At the same time it aggregates regional and global perspectives on the spread of plant health problems.

By collating feedback and observations from the network of plant clinics, Plantwise creates a unique source of information on what is being seen at the local level. At critical mass of clinics, these data, together with analysis informed by scientific knowledge, will provide a powerful global early warning system for plant health vigilance. Countries and regions can be alerted to potential threats and able to prepare improved local responses to problems and climate change.

These examples show the potential of today's information and communication technologies to make existing knowledge more widely available. This can give extension and advisory services new opportunities to use their limited resources to communicate with farmers in ways that have greater reach, frequency and impact (Figure 6).

Supporting farmers to make change

To enable change to take place, conditions need to favour economic as well as biological sustainability. A sustainable farming community is one in which the farmers make a living that motivates them to stay and farm rather than seeking higher income in the cities. There is now widespread agreement that improving smallholder productivity is essential for increasing food supply, but there must

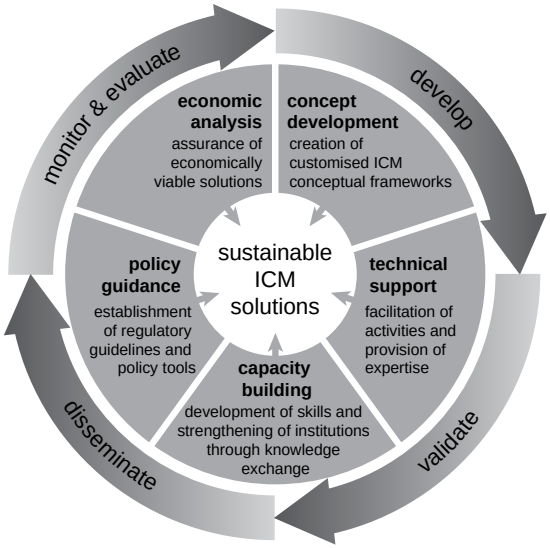


Figure 7. CABI aims to establish a virtuous circle of actions, support and guidance, to help smallholders achieve sustainable integrated crop management (ICM).

also be a vision of how to help smallholders make a business out of their farming (such as is indicated in Figure 7). For farming to become a profitable and respected rural profession farmers need to be able to connect to markets and get a fairer share of the value they create when they improve the yields of their crops. For example, in Tanzania, CABI has helped tomato growers adopt integrated pest management techniques to reduce pesticide residues on the produce. It has helped the growers establish producer clubs and develop branding for their produce so as to sell into higher value urban markets.

In the implementation of innovation, partnerships with the private sector will be an important enabler. At the most basic level, new seeds, inputs or technology must be available to farmers through local agro-dealers at reasonable prices and in appropriate quantities. Farmers also need access to financial products in the right package sizes.

For example, in recent work funded by the Common Fund for Commodities (CFC), CABI helped coffee farmers in Rwanda and Ethiopia produce higher quality coffee by introducing more effective methods of drying the coffee cherries. Farmer field schools were used to teach farmers the new processing techniques and producer clubs enabled them to achieve 30% price premiums for the better product that resulted. However, many of the farmers could not afford the capital outlay required to buy the simple equipment needed to improve the drying process. Therefore, in a second phase of the project, again supported by CFC, CABI partnered with Rabobank of the Netherlands to establish lines of microfinance credit to enable farmer groups to purchase the driers.

Farmers also need help to manage uncertainty. Agriculture involves making everyday decisions in response to unpredictable conditions and unknown

risks. The poorer the farmer, the greater the risk and impact of making a wrong decision or failing to get advice on time. Even with good advice, the initial cash outlay and financial risk of new approaches may seem too much for a poor farmer whose family depends on the income from the farm. Farmers are naturally cautious and, as a result they often stick with tried and trusted varieties or approaches. Novel micro-insurance initiatives, such as Kilimo Salama pioneered by the Syngenta Foundation, help reduce the risks by selling insurance against adverse weather effects (such as drought or flood) along with the seeds. Mobile phone technologies are stimulating innovation by making these novel offerings of micro-credit and crop micro-insurance possible through reducing the acquisition and transaction costs, as well as offering novel methods of payments (m-PESA, for instance: 'mobile-money' in Swahili).

In summary, meeting the challenge of feeding a growing world population will require farmers to innovate so as to produce more from less. This is not just about funding agricultural research focused on growing more, but also about building capacity and spreading existing knowledge to help us lose less.

If we are to succeed in this endeavour we must develop better methods of disseminating technology, assess and validate the outcomes to learn what works, and integrate this within a framework of supportive economic and environmental policies.

There must be balance between the imperative to lift yields and outputs and at the same time secure the sustainability of the environment within which that production takes place.

To quote Gro Harlem Brundtland, former Prime Minister of Norway and Director General of the World Health Organization:

> *You cannot tackle hunger, disease and poverty unless you can also provide people with a healthy ecosystem in which their economies can grow.*

References

IPCC (2007). *Climate Change 2007*. Fourth Assessment Report. Intergovernmental Panel on Climate Change.

Under Dr Trevor Nicholls' leadership, CABI has developed a strategic focus on providing knowledge to enable poor rural farmers in the developing world to grow more, raise quality and increase income. Previously, his career covered experience of building international businesses in the genomics and life science industries serving major pharmaceutical, biotech and academic clients. He has broad experience of initiating change and restructuring organisations, ranging from start-ups to FTSE 100/Nasdaq quoted companies. Trevor holds a BA and D.Phil in Biochemistry from the University of York and Diploma qualifications in Marketing (CIM) and Company Directorship (IoD).

Email: t.nicholls@cabi.org

Can we free the world of hunger and Malthus's shadow forever?

Dr Shenggen Fan
International Food Policy Research Institute

Abstract

In a little over a decade, the global population is expected to reach 8 billion. The task of feeding this growing population will become harder with rising natural resource constraints, declining or stagnant crop productivity, more frequent extreme weather events, and climate change. These challenges, especially the ensuing increase and volatility of food prices, threaten global food and nutrition security. The Malthusian prediction that population growth would eventually outpace agricultural production growth can be prevented. Technological successes in food and agriculture, such as the Green Revolution, demonstrate that rapid productivity increases in food production can be achieved. However, the goal of achieving global food and nutrition security must encompass food availability, accessibility, and utilisation, as well as the stability of all of these conditions over time. This paper highlights major actions needed to achieve these important objectives while simultaneously adopting a sustainable development approach. The actions include:

- investments in agriculture and technological innovations to boost productivity, especially smallholder productivity, enhance the nutritional value of food crops, and increase resource-use efficiency;
- productive social safety nets to protect poor and vulnerable groups, especially women and children, to ensure their access to nutritious and healthy food in the short run, and improve their human capital for long term prosperity;
- global coordination to reduce food price volatility, including establishing strategic emergency food reserves, ensuring open trade, and eliminating grain-based biofuel production.

Malthus's prediction in a modern context

Two centuries ago, Thomas Malthus made the assertion that population growth, if unchecked, would eventually outpace growth in food production. Through his influential piece, 'An Essay on the Principle of Population', he suggested that food shortages would be imminent, basing his assertion on the theory that food production increases in a linear fashion while population grows geometrically (Malthus 1798). Today, however, Malthus's prediction has not materialised. Hunger and malnutrition persist, but largely due to unequal distribution or access resulting from factors such as poverty, political disadvantage and conflict, rather than an overall shortage in food. What Malthus did not take into account in his prediction was the role of technological innovations in agriculture, in

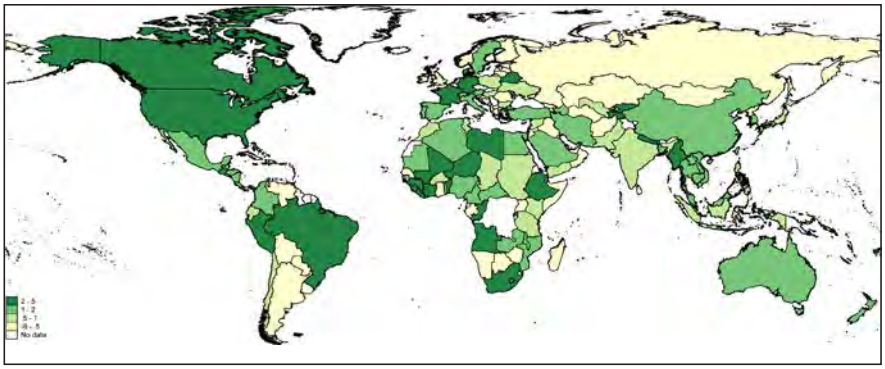


Figure 1. Average annual agricultural growth in total factor productivity (%), 1995–2009 (Alejandro Nin-Pratt & Bingxin Yu, pers. comm. October 2011).
White = no data. Cream = -6 – 0.5%. Green: dark 2–5%, paler 1–2%, palest 0.5–1%.

combination with policy and institutional innovations, which have allowed food production, by and large, to keep pace with population growth (Trewavas 2002).

Advances in technology, such as improved high yielding seed varieties and the use of chemical fertilisers, have helped combat food insecurity for millions in recent decades, as well as lift many out of poverty. In this, policy and institutional developments have been a catalyst. Changes and innovations in policy have increased investment in agricultural research, enabled greater access to credit for farmers, allowing them to access improved inputs more easily, and improved other key agricultural components, including irrigation, rural infrastructure, land area, and market access. The Green Revolution is the most prominent example of the preceding, where a concerted effort beginning in the 1960s contributed to a doubling of world cereal production, most notably throughout Asia (Hazell 2002).

Growth in global agriculture has been steady and is now productivity driven, but it is uneven

Growth in global agricultural output has steadily increased in recent decades — averaging 2.7% per year during the 1960s and between 2.1% and 2.5% per year in each decade that followed (Fuglie & Wang 2012) — and has become increasingly productivity driven. Total factor productivity (TFP) has increased dramatically in many areas, but growth varies significantly across countries because input intensification, resource-use efficiency and their effects on productivity differ greatly among developed and developing nations (Fuglie & Wang 2012). In developed countries, resource use has been falling steadily for the past several decades while output has continued to grow in most areas, suggesting that input and resource use are becoming more efficient. Results for developing countries, however, are mixed. For some countries, especially Brazil and China, as well as others in South-East Asia, North Africa, and Latin America, TFP growth has been relatively high in recent decades. For other developing countries, TFP growth has been relatively low, especially in Africa south of the Sahara (SSA) (Figure 1). An average of country-level TFP measures for SSA from 1964 to 2006 shows

that annual growth was near 0% (0.02) (Yu & Nin-Pratt 2011) where many countries do not have access to quality inputs, are using inefficient and outdated machinery and irrigation techniques, and do not have policy environments which effectively support agricultural development.

Current and future challenges remain large

Significant strides have been made in freeing the world from Malthus's shadow over the past two centuries, especially in recent decades. However, many current and future challenges remain large and complex, and will threaten future food production.

Global hunger and undernutrition still persist at significant levels. Based on the International Food Policy Research Institute (IFPRI) 2012 Global Hunger Index, over 50 countries have levels of hunger that are 'extremely alarming', 'alarming', or 'serious'. A large portion of those are in Asia and SSA (von Grebmer et al. 2012). According to the UN Food and Agriculture Organization (FAO), nearly 870 million individuals on the planet are undernourished, roughly one out of every eight people. Of these, 850 million live in developing countries (FAO 2012). Further, micronutrient deficiencies plague more than 2 billion people on the planet. Again, a significant portion of this burden falls on the developing world (WHO & FAO 2006).

A growing, urbanising, and more affluent global population will put enormous stress on global food and nutrition security going forward. The Earth will not only need to support more individuals in coming decades but, as urban populations increase and global incomes grow, people will demand more and better food. They will move away from traditional staple crops towards a more diversified diet consisting of larger quantities of meats, vegetables, and fruits. By 2050, the global population is expected to reach 9.3 billion (UN 2011). A significant portion of this growth will occur in urban areas of developing countries. From 2010 to 2050, the world's urban population is expected to increase by 75%. Further, most of this growth is predicted to occur in Africa and Asia, where urban populations are estimated to increase by 47% and 45%, respectively. Global per capita income is expected to more than double throughout developing countries in coming decades, from $2905 in 2012 to $6393 in 2030, and triple globally, from $7754 to $12,045 for the same period (ERS USDA 2012).

Growing natural resource constraints will have a significant effect on agricultural productivity. Resource constraints will mean the increasing demand for food resulting from a growing and more affluent global population will have to be met with less means. A survey of land and water — the two most essential components to agriculture — illustrates this. Arable land degradation is occurring rapidly, and nearly a quarter of all global land area has been affected by degradation. This is equivalent to a 1% loss in global land area annually. That area of land could produce 20 Mt of grain per year (IFPRI 2012). In terms of water stress, 2.4 billion people, or 36% of the global population, live in water-scarce areas, and 22% of the world's gross domestic product (GDP) is derived from water stressed areas as well. Going forward, if agricultural resource use continues at its current rate, 52% of the global population, 45% of global GDP,

and 49% of global grain production will be at risk by 2050, as a result of water stress (Veolia Water 2011).

Moreover, the argument has been made that not only the scarcity of resources but also the services provided by ecological systems impose limits to the carrying capacity of the planet (Arrow et al. 1995). Similarly, human activities, including innovation, are seen as having driven global environmental changes to such an extent that they are set to push the planet's biophysical systems and processes out of their current stable state and beyond planetary boundaries, thus eventually affecting human well-being and in particular harming the poor (Stokstad 2005). Hence, to avoid a Malthusian scenario of eventual widespread misery, humanity does not only have to sustain a growing population from a limited resource base; the challenge is to do so without upsetting ecological balances (Rockström et al. 2009).

Climate change is another major challenge, and stands to exacerbate all of the preceding. The effect of a changing climate — including variations in seasonal patterns, temperature and precipitation — will negatively affect the productivity of many farmers around the world, especially those in developing countries. As conditions change, adaptation will need to take place. This adaptation will compete with resources that could be used for other purposes, and farmers all over will have to adapt. For the aggregate food system, climate change poses the risk of inconsistencies in food supply, price volatility, stress on national governments attempting to respond through policy measures, and imbalanced trade (Nelson et al. 2010). Biofuel production will also put pressure on the food system, especially if it is produced from food crops. Biofuel production is expected to nearly double from 2009–11 to 2021 (OECD & FAO 2012).

An integrated approach is needed

An integrated approach is needed to both enhance global food and nutrition security and free the world of Malthus's shadow. As Malthus saw it, careful policy-making is needed to achieve global food security. However, the picture is more complex than simply meeting population growth with technology-driven increases in the aggregate food supply. The challenge for humanity today is to improve agricultural productivity, but also to address the problem of distribution by implementing policies that help allocate agricultural output across societies, and within societies across individuals. In addition, the international community needs to promote efficient and sustainable use of resources, drive the development of renewable energy sources, and protect and where necessary restore the functioning of crucial ecosystems and biophysical processes. In this, it is critical to improve smallholder productivity and resilience, increase global coordination aimed at reducing price volatility, promote low carbon agriculture, and boost developing country capacity. Major actions needed are as follows.

1. Accelerate investments in agriculture, especially in smallholder productivity, improve nutrition, and increase resource-use efficiency

Boosting smallholder productivity is crucial not only for advancing food security, but in raising the incomes of farmers and spurring overall economic growth, especially in resource-rich low-income countries. Increased investments must

be made in agricultural research and development that focus on:

- new agricultural technologies which have low adoption barriers and are suitable for small farmers;
- rural infrastructure which provides market access for farmers;
- providing access to quality inputs, such as high-yielding seeds and synthetic fertiliser; and
- institutional innovations required to promote the use of new technologies, including financial (e.g. community banking) and extension services, as well as risk management mechanisms (e.g. weather-based index insurance).

Productivity investments should also be used as a basis for improving the nutritional and health status of consumers, especially women and children. Biotechnology and biofortification have the potential to improve both the productivity and nutritional outcomes of specific crop varieties. For example, from 2007 to 2009, HarvestPlus (a joint venture between the International Center for Tropical Agriculture (CIAT) and IFPRI) and its partners disseminated new orange sweet potato varieties to more than 10,000 farming households in Uganda, resulting in significant reductions in vitamin A deficiencies throughout the country (HarvestPlus 2012). Next to this, although it is critical to forge links between agriculture and nutrition through the development of more nutritious staple food crop varieties, it is also important to have safety regulations to ensure that agricultural intensification does not harm people's health, and more efficient postharvest handling to reduce deterioration in the nutritional quality of foods.

Investments are also needed in resource-efficient technologies and practices which have high payoffs. This entails the adoption of inputs and practices which boost productivity and reduce the current use of essential resources such as land and water. For example, 'business as usual' approaches to water management have been estimated to expose 4.8 billion people (or 52% of the world population) to severe water scarcity by 2050. Sustainable water management can de-risk from water stress more than 1 billion people and roughly $17 trillion of GDP (Veolia Water 2011). Further, to fully reflect the value of natural resources and set appropriate incentives, the full cost of environmental degradation as well as all benefits of ecosystem services should be taken into account by decision makers. The prices of food and natural resources must include social and environmental costs and benefits, such as impacts on climate change and health, which can be achieved through taxation, regulation, and improved economic incentives. Together with research, extension services, and communication campaigns to build awareness, higher costs will promote the adoption of resource-saving technologies and practices while encouraging all actors along the food value chain to reduce waste.

2. Scale-up productive social safety nets to protect poor and vulnerable groups

Better-targeted and more productive social protection policies are needed, both to cushion livelihood shocks that are facing poor and vulnerable groups, and to offer opportunities to escape poverty. Agricultural growth alone is not sufficient.

Possible interventions include conditional cash and food transfers, maternal and child health and nutrition programs, public works programs and insurance schemes. New approaches, such as cross-sectoral social protection initiatives, should be explored to reach the poor more effectively. For example, families who had access to Ethiopia's Productive Safety Net Programme, implemented in 2005, and other complementary food security programs were able to build up more assets, improve their food security, and attain higher crop yields than families that did not participate in these programs (Gilligan et al. 2008).

3. Improve global coordination to reduce food price volatility

National governments should be encouraged to eliminate harmful trade restrictions, such as countercyclical trade policies particularly banning food exports, and refrain from imposing new ones, in order to reduce food price volatility and enhance the efficiency of agricultural markets. Although export bans may help to secure domestic food supply in the short term, they have been shown to exacerbate global price hikes, thus hurting the poorest of the poor, particularly in import-dependent countries. In addition, trade can also increase the efficiency of natural-resource use, when it helps optimise resource allocation across countries in line with their comparative advantages. For example, countries can import crops that were grown under rainfed conditions instead of producing them using irrigation.

A regional emergency grain reserve is also needed to address food price volatility. Owned and managed by an institution like the World Food Programme, such a reserve should be created through donations of grain stocks from large food exporters, such as the United States, Canada and France, and large food producers, such as China and India. This emergency reserve should be strategically positioned in these large food-producing countries and, more importantly, in food-importing poor countries, such as Bangladesh, for efficient and timely access in times of crisis. To some extent, this process is already underway. The emergency rice reserve of the Association of South-East Asian Nations plus China, Japan, and South Korea (ASEAN+3) is an example and a step in the right direction.

Food crop demand for biofuels, particularly in the United States and European Union, must also be cut substantially to help relieve the pressures on both domestic and global food markets and reduce food price volatility. By supporting effective biofuel policies and technology investments, and removing counterproductive measures such as subsidies that encourage the use of food crops for fuel production, public policies can help to lower the cost of food.

A mechanism should also be set up to systematically monitor developments in food supply, consumption, prices and trade, as well as agricultural commodity speculations. Governments should use existing platforms, such as the IFPRI Food Security Portal, FAO's World Food Situation, and G20's Agricultural Market Information System, to generate solid evidence on developments in global markets and their likely implications, in order to avoid generalisations and thus potentially misguided responses by member states.

4. Invest in agricultural climate-change mitigation/adaptation and promote low-carbon agriculture

Agricultural investments should target measures that provide productivity, mitigation, and adaptation benefits. 'Triple win' solutions are required to increase the adaptive capacity of farmers to climate change, promote the mitigation of greenhouse gases, and boost crop productivity in a synergised manner. A recent study from Kenya shows several triple-win practices which can help farmers in developing countries combat climate change while boosting their agricultural output. For instance, soil nutrient management using combinations of inorganic fertiliser, mulching and manure, proved to increase soil carbon sequestration and crop yields. That helped to improve farmers' incomes and create a buffer against the effects of climate change. Leaving crop residues on cropped fields also proved to have high potential for carbon sequestration and yield increases, though results varied depending on location, portions of residues left and management practices. Overall, triple-win innovations and related technology must be smallholder friendly, and policies should mitigate risk for rural farmers in switching to new technologies and practices (Bryan et al. 2011).

5. Support country policymaking capacity and enhance institutions and governance in agriculture and the system

Improving the ability of low-income countries to develop, test and evaluate new policies which support agricultural development is crucial. Policies should come from developing countries to maximise local impact and should be contextually sound but also designed with the global agenda in mind. Countries must develop capacities for data collection in order to improve evidence around what policies have, and have not, been successful. Country-owned policies should be continually tried, evaluated, adjusted and tried again before being scaled-up. The international community should play a role in facilitating this process through knowledge, resources and best-practice sharing.

References

Arrow K. et al. (1995). Economic growth, carrying capacity, and the environment. *Science* 268: 520–521. http://dx.doi.org/10.1126/science.268.5210.520

Bryan E. et al. (2011). *Agricultural management for climate change adaptation, greenhouse gas mitigation and agricultural productivity: insights from Kenya*. http://www.ifpri.org/sites/default/files/publications/ifpridp01098.pdf

ERS USDA (2012). *Real historical and projected GDP per capita and growth rates of GDP per capita for baseline countries/regions 2000–2030*. Economic Research Service, US Department of Agriculture. http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx

FAO (2012). *The state of food insecurity in the world*. Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/016/i3027e/i3027e.pdf

Fuglie K. & Wang S. (2012). *New evidence points to robust but uneven productivity growth in global agriculture*. http://www.ers.usda.gov/media/909993/globalag.pdf

Gilligan D., Hoddinott J. & Taffesse A. (2008). *The impact of Ethiopia's Productive Safety Net Programme and its linkages*. http://www.ifpri.org/sites/default/files/publications/ifpridp00839.pdf

HarvestPlus (2012). *Key findings for orange sweet potato*. http://www.harvestplus.org/content/key-findings-orange-sweet-potato

Hazell P. (2002). *Green Revolution: Curse or blessing*. http://www.ifpri.org/sites/default/files/pubs/pubs/ib/ib11.pdf

IFPRI (2009). *Millions fed: Proven successes in agricultural development.* http://www.ifpri.org/sites/default/files/publications/oc64.pdf

IFPRI (2012). *Global Food Policy Report 2011*. International Food Policy Research Institute. http://www.ifpri.org/sites/default/files/publications/oc72.pdf

Malthus T. (1798). *An Essay on the Principle of Population*. http://www.esp.org/books/malthus/population/malthus.pdf

Nelson G. et al. (2010). *Food security, farming, and climate change to 2050: Scenarios, results, policy options*. http://www.ifpri.org/sites/default/files/publications/rr172.pdf

OECD & FAO. (2012). *OECD-FAO Agricultural Outlook*. Organization for Economic Cooperation and Development & Food and Agriculture Organization of the United Nations. http://www.oecd.org/site/oecd-faoagriculturaloutlook/database-oecd-faoagriculturaloutlook.htm

Rockström J. et al. (2009). A safe operating space for humanity. *Nature* 461: 472–475. http://dx.doi.org/10.1038/461472a

Stokstad E. (2005). Taking the pulse of Earth's life-support systems. *Science* 308: 41–43. http://dx.doi.org/10.1126/science.308.5718.41

Trewavas A. (2002). Malthus foiled again and again. *Nature* 418: 668–670. http://dx.doi.org/10.1038/nature01013

UN (2011). *World urbanization prospects, the 2011 revision*. http://esa.un.org/unup/CD-ROM/Urban-Rural-Population.htm

Veolia Water (2011). *Finding the blue path for a sustainable economy.* http://www.veoliawaterna.com/north-america-water/ressources/documents/1/19979,IFPRI-White-Paper.pdf

von Grebmer K. et al. (2012). *Global Hunger Index 2012*. http://www.ifpri.org/publication/2012-global-hunger-index

WHO & FAO (2006). *Guidelines on food fortification with micronutrients*. World Health Organization & Food and Agriculture Organization of the United Nations. http://www.who.int/nutrition/publications/guide_food_fortification_micronutrients.pdf

Yu B. & Nin-Pratt A. (2011). *Agricultural productivity and policies in sub-Saharan Africa*. http://www.ifpri.org/sites/default/files/publications/ifpridp01150.pdf

Dr Shenggen Fan is the Director General of the International Food Policy Research Institute (IFPRI). After joining IFPRI as a Research Fellow in 1995, he led IFPRI's program on public investment and later became director of IFPRI's Development Strategy and Governance Division. Dr Fan is a leading researcher on pro-poor development strategies in developing countries. He has published widely in the areas of agricultural R&D policy, public investment, transition economies and agricultural development strategies. Dr Fan received his PhD in applied economics from the University of Minnesota and his MSc and BSc from Nanjing Agricultural University, China.

Email: s.fan@cgiar.org

Conference overview and summary

Dr Denis G. Blight AO
Crawford Fund

Abstract

The Crawford Fund's Annual Parliamentary Conference for 2012, 'The Scramble for Natural Resources', addressed a question of fundamental importance to Australia and to the international community: that is, how to feed, adequately, an extra 2 or 3 billion people within a few decades without irretrievably damaging the planet. The consensus response — from the panel of speakers and the extended question and answer session — was, in short, that the world probably has enough land, nutrients and water and, one might infer, ingenuity, in aggregate, to meet the challenge. Yet a food-secure world will only be possible if 'major distributional and degradation problems' are addressed with efforts to close the gap between achievable and actual yields, as well as increased investment in research to raise yield potential. Increased production, based on a better understanding of interactions between agriculture and natural ecosystems and urban and rural development, enables, at least theoretically, increased yields, lower costs and reduced erosion and water degradation. Even with all of this, however, food price spikes and horrifying episodes of famine seem likely to recur, requiring specific policy interventions and emergency responses — including to changing climate and weather patterns.

Australia can contribute to a food-secure world by growing and exporting as much food as is possible within constraints formed by our natural resource base and by market demand and prices. Within these limits, and with increased allocations to research, Australia could become one of a number of food bowls. By itself Australia cannot feed more than a fraction of the world. Its contribution through research, however, could be globally significant and contribute beneficially to the diets of 100 million or more.

Summary of the papers[1]

In opening the conference Senator the Hon. Bob Carr[2], Foreign Minister for Australia, defined a food-secure world as one in which there is sufficient nutritious food for all. He stressed, in particular, the need to avoid stunting in children due to inadequate nutrition, a problem which if left unattended would seriously affect the capacity of a generation to contribute to society, constraining individual as well as national growth. The Minister also announced that the first

[1] This summary is partially based on a review by Professor Andrew Campbell in *The Conversation*, 18 October 2012, https://theconversation.edu.au/Australia-and-the-global-scramble-for-natural-resources. Direct extracts from the review and other speakers are shown within quotation marks. In some cases, speakers' remarks have been paraphrased.

[2] Senator the Hon. Bob Carr, Opening Address, see pp. 8–9.

conference of the newly established Australian International Food Security Centre[3] would be held in late November 2012 in Sydney.

In the opening session, the three keynote speakers[4,5,6] painted a global world food scenario characterised on the one hand by a burgeoning demand for food from a growing global population that is living longer and consuming more, not always sensibly, especially as a global middle class numbering around 4 billion becomes a reality. Further, there are now real signs of stress in the global biosphere: biophysical realities can no longer be ignored and it is the task of conferences such as this one to bring that cold reality to the fore by public discourse, they said.

On the other hand, revolutions in the life sciences and information technology mean that biology and physics can now work in harmony to increase food production and distribution in ways that reduce pressures on the environment. Given absolute limits on the availability of land (which were spelt out with authority in the session), more intensive agriculture, based on new and existing higher-yield technologies applied on better lands already under cultivation, could reduce degradation of marginal lands. Precision agriculture could fine-tune use of water and other essential inputs. Mobile phones, now widely available, could ensure farmers could have access to the latest information including on weather.

Land — lots of land

According to the review by Dr Derek Byerlee[4], additional land is available for cultivation (about 450 Mha) especially in sub-Saharan Africa and parts of Eastern Europe, Latin America and Australia. Strong commodity prices and relatively higher returns from farming, together with the availability of cheap land in some countries, have translated into a sharp rise in foreign and domestic investment into farmland, the so-called 'land rush'. Where land governance is poor and institutional capacity weak, there have been many failures, especially in sub-Saharan Africa and parts of Asia. Australia, on the other hand, has skilled farmers and strong institutions so that with the advent of a transparent land register it has little reason to be concerned about foreign investment in farmland. Moreover, Australia has much to gain from freer agricultural trade and its corollary — unrestricted (but monitored) foreign investment in farmland. It could continue to lead the world in advocacy for these policies.

New lands could make a contribution to increased food production, but as Professor Jonathan Foley[5] and Dr Frank Rijsberman[6] pointed out, most increased food production (probably more than 75%) will have to be derived from increased productivity — from raising the achievable yield ceiling and by closing the gap between actual and achievable yields. Speakers said both are possible.

Increased production targets have to be calibrated against increased and changing demands for foodstuffs. Instead, demand per capita for rice, for

---

[3] http://aciar.gov.au/aifsc/

[4] Dr Derek Byerlee, agricultural specialist, 3rd keynote speaker, see pp. 28–38.

[5] Professor Jonathan Foley, University of Minnesota, 2nd keynote speaker, see pp. 21–27.

[6] Dr Frank Rijsberman, CGIAR Consortium, 1st keynote speaker, see pp. 10–20.

example, is not increasing in emerging economies; demand for meat and dairy products and for fruit and vegetables is growing as diets change with prosperity and information-based choices, but not always for the better. Changing diets, especially towards meat and dairy production based on feed grain, can increase pressure on the Earth's resource base — a trend compounded by the use of grains for biofuels.

Raising the yield ceilings

A revolution in the life sciences, linked to dramatic changes in information and communication technologies, provides the scope for growth in both achievable and actual yields, according to Rijsberman. He referred in particular, to the falling cost of DNA sequencing, which opens the way for identification of beneficial plant and animal traits that could facilitate and enrich conventional approaches to crop and livestock breeding[7].

The IT revolution has introduced the practicality of laser- and GPS-based land levelling, satellite information to predict crop growth and relatively cheap sensors of such factors as soil moisture and weather, the conference was told. In addition, in a point emphasised later by Dr Trevor Nicholls[8], mobile telephony — a technology from private sector investment in R&D — opens avenues for extension services and market information. Nicholls also pointed to the promise of biotechnology through potential breakthrough research, including work being undertaken at the Australian National University on transforming photosynthetic efficiency.

Closing the gap in nutrient and water use and in natural ecosystem management

As Jonathan Foley made clear, global yield variability is heavily controlled by fertiliser use, irrigation and climate. Eliminating nutrient overuse in parts of the globe, and encouraging increased use where it is needed, can potentially deliver the holy grail of increased production without adverse environmental consequences. In a similar vein, Dr Andrew Noble[9] argued that new approaches to sustainable agriculture could have a major and beneficial impact on global land and water irrigation. A better understanding of interactions between agriculture and natural ecosystems enables, at least theoretically, increased yields, lower costs and reduced erosion and water degradation, he said.

As Campbell comments in *The Conversation*, we need 'more sophisticated land use planning and integration tools to help us work out how best to fit competing land and water uses'.

---

[7] The conference largely avoided debate on genetically modified organisms (GMOs) and organic farming except that Foley put their contributions to food production globally at 10% and 1% respectively. He stressed that he was not arguing against either, but he urged that policy attention should not be distracted from the main issues by aspects of the debate between their relative benefits. There was also a discussion in the Q&A session on the need for balance between crop improvement research and agronomy, which is reported below.

[8] Dr Trevor Nicholls, CABI, see pp. 96–106.

[9] Dr Andrew Noble, International Water Management Institute, see pp. 39–51.

Dr Nteranya Sanginga[10] also believes that production system intensification is key to achieving system-level outcomes in Africa especially through: increasing agricultural production per unit land area; reduced environmental externalities; improved resource-use efficiency; and increased supply of ecosystem services. A key issue is the restoration of soil fertility in Africa, he said, because of limited returns to crop breeding, high rates of nutrient depletion (Africa has old and degraded soils) and crop and soil management challenges. The importance of soil fertility had been ignored until around 1997. So-called low-input sustainable agriculture had failed because of lack of adoption of technologies by famers, no doubt for good reason. He argued that soil fertility and organic matter restoration should partly be regarded as a social cost with environmental benefits — carbon sequestration in African soils is, he said, almost tantamount to soil fertility conservation. Conservation agriculture was an essential component of reform in agricultural practice, he said.

Forest lands — more than just trees

Many developing countries face a dilemma: should forests be cleared and cut for higher incomes and to ensure food security? Do forest conservation and food security really present a 'zero-sum' trade-off? Echoing a point made by Foley, Dr Christine Padoch[11] argued not. In reality, she said, forest resources are essential to the daily livelihoods and a substantial portion of the diet of 'a billion people'. In two case studies in West Africa, CIFOR had shown that women derive 53% and 46% of their income, respectively, from forest products; in a third study the figure was 12%, she said.

Human activities pushing Earth systems beyond stability

To date, uptake of new approaches in nutrient delivery and sustainable agriculture (and land use planning) has been disappointing. According to Noble, human activities have pushed Earth systems beyond the stable state of the Holocene into the Anthropocene. Greater policy and media attention to these issues is vital.

Somehow forests, said Padoch, need to be 'valued' by defining food security as more than just calories. Studies show a positive correlation between forest cover and dietary diversity, and vitamin A and iron are among micronutrients supplied by forest products; 5–6 Mt of bush-meat are eaten annually in the Congo Basin.

Furthermore, forests do much more than provide food: they provide water filtration and regulation, pollination, temperature regulation, aquatic resources and genetic resources.

There is no single silver bullet to resolve this dilemma, she said; forest governance is key, and decisions to convert forests should include the interests of people who depend on them, and take into account the environmental services that forests provide. Decisions to keep 'forests as forests' could be

---

[10] Dr Nteranya Sanginga, International Institute of Tropical Agriculture, see pp. 77–95.
[11] Dr Christine Padoch, CIFOR, Indonesia, see pp. 69–76.

hard-headed, based on sound planning of functional landscapes and direct and indirect contributions to food security.

Foley also reflected on the impact of agriculture on climate change. Agriculture makes the single biggest impact on atmospheric carbon, mainly because of clearing of forests for agriculture with only limited gains in terms of food production in a global context, he said, especially when the potential impact of climate change is taken into account. Nicholls illustrated some of those impacts on human activities by drawing on summaries of 69 IPCC studies showing the effects of higher temperatures on yield growth, with a greater deleterious impact in the tropics compared to temperate zones[12].

Lose less, feed more

Tracing 'build or buy' options to make more food available, Nicholls added two sets of actions: (i) reducing competition for resources from weeds, lessening the impact of pests and diseases, cutting losses in transit and storage; and (ii) moving farmers from subsistence to surplus or earning more through productivity gains, higher value crops and higher market values. He mentioned gains of 2.4 milllion tonnes that could be won by halving pest and disease loss, which, along with current production levels and increased production through the use of hybrid varieties, could convert the Philippines from a net rice importer to an exporter. He told us of community videos in Bangladesh, made by the village women to communicate best practice seed management, which successfully raise awareness of proper practice because they are relevant and credible. He spoke of successful agro-advisory services in India involving 4 million users receiving five free 'push' messages by mobile phone each day, and the development of GSMA in Kenya and Ghana. He promoted integrated pest management as one means to reduce costs to farmers and damage to the environment.

The urban dimension

National food plans or land use planning have to engage with urban development. More than half of the Earth's population are urban dwellers, and while growth of urban conglomerates might slow, urbanisation will continue to interact both favourably and unfavourably with food production. Professor Xuemei Bai[13] illustrated the 'land grab' effect of urbanisation with dramatic before and after photographs of the expansion of Shenzen City in China between the years 1980 and 2005. Whilst the absolute amount of land dedicated to urban development is modest (roughly 1% of the Earth's surface is urban; this might grow to 2% by 2030), the interactions are rich with potential and risk. Urbanisation, in one sense a consequence of the civilising impact of agricultural societies, could drive economic growth, national prosperity and demand for more and better foods. There are opportunities for growth in social and economic capital for agriculture in peri-urban areas. Urbanisation can also

[12] Further information on the impact of climate change on agriculture and vice versa can be found in the Proceedings of the Crawford Fund's Parliamentary Conference (2008) on Agriculture in a Changing Climate, available at www.crawfordfund.org.

[13] Professor Xuemei Bai, the Australian National University, see pp. 60–68.

increase social vulnerability in traditional farming communities in the same areas, and cities can accelerate dietary changes for better or worse.

Bai called for an 'integrated approach, rather than the dichotomised approach that is the norm today in research and policy for urban development and for the food production debate', a sentiment echoed by Campbell who claims that if 'the [Australian] National Food Plan fails to engage urban dwellers and the health system, a major opportunity to reposition Australian agriculture will be lost'.

Minerals, energy and agriculture

The need for an integrated approach was also a feature of the presentation by Professor Chris Moran[14] which challenged some popular factoids about the so-called trade-off between mining and agriculture. Land occupancy by mining is relatively small for each mine although wider impacts of dust and water transport and pollution need careful management; but mining is a minor competitor for land and water and a minor contributor to land degradation compared to poorly managed agriculture. The relative contribution of agriculture and mining to national incomes varies between countries and over time. Cotton, for example, has been a major factor in Australian trade with China, Japan and Thailand; mining has assumed importance in exports in the last decade. He decried over-generalisation and alarmist communication of potential impacts that were not science-based; nor were they likely to lead to good governance and practical outcomes. There were, he said, co-resource exploitation opportunities where for example soil and gas resources could convert marginal entities into economically successful ones. The challenge for the political capability and social maturity of societies is to find ways, through knowledge and sound policy, to manage multiple resource-extracting activities in parallel[15].

Institutional and policy innovations

The predictions of Thomas Malthus, two centuries ago, that food production would eventually fall short of population growth, leading to 'misery, vice, sickness and starvation' did not eventuate in full because of technological, institutional and policy innovations. To 'free the world of Malthus's shadow', Dr Shenggen Fan[16] called for an integrated approach to enhance global food security. Technological innovations were well described by other speakers and rehearsed by Fan but he emphasised the importance of institutional and policy innovations, with a mix of broad-based agricultural development such as had been seen in China, India and Vietnam, and pragmatic and evolutionary trial and error practices in China. He gave an overview of total factor productivity growth, pointing to the changing impacts of capital, fertiliser, oil price increases, irrigation and land; the variability of productivity growth across countries; the uneven improvement of land and labour productivity across regions; and

---

[14] Professor Chris Moran, Sustainable Minerals Institute, see pp. 52–59.

[15] A further discussion on this question is available in Brief 2 of the Emerging Priorities Series, published by the Crawford Fund.

[16] Dr Shenggen Fan, The International Food Policy Research Institute, see pp. 107–114.

substantial variations in the ratio of actual and potential yields. He highlighted the global loss of primary production because of degradation of natural resources, and physical and economic water scarcity. A business-as-usual approach, he said, would, by 2050, put at risk 52% of the global population, 49% of global grain production and 45% of global GDP.

His solutions embraced:

- accelerated investments in agriculture, especially in smallholder productivity;
- a scaling-up of social safety nets for the poor and vulnerable;
- improved global coordination to reduce food price volatility (including through global and regional grain reserves), transparent and free global trade, a halting of grain-based biofuel production, and monitoring of food prices and speculation;
- investments in agricultural climate-change mitigation and adaptation;
- promotion of low carbon agriculture, where he illustrated potential synergies between productivity, climate-change adaptation and greenhouse gas mitigation through a case study in Kenya;
- support for enhanced developing-country capacity to originate policy that would maximise the local impact of a global reform agenda; and
- research to provide evidence of policies that have worked and those that have not.

Australia, as a long-term player in advancing global food and nutrition policies through AusAID and ACIAR and the leadership of Sir John Crawford, has an active role to play, especially if it continues to engage in broader, more innovative and productive partnerships.

Q&A session: Topics and summarised answers

The main Q&A session, which I moderated, was held at the end of the day (with a shorter one after the breakfast the next day), and this year's questions could be submitted beforehand via Twitter or texting, as well as from the floor.

Social, cultural, institutional and political constraints to the implementation of science-based strategies for food security, including the uptake of new technologies and farming practices

Whilst we cannot give short shrift to the challenges of 'changing society' it was the duty of biophysical scientists to establish the 'non-negotiable' biophysical realities; realities which otherwise might be ignored by society's political leadership. Fortunately, biology and physics are now working together on a narrative on constraints and opportunities that might 'point the way' on feeding the world without irretrievably damaging the biosphere.

The contrast between crop yields on research stations and on farms

In their analyses, Foley, Rijsberman and Sanginga had made much of the gap between achievable and actual yields. Several questions related to this gap. Given the claimed relative efficiency through uptake of new technologies by large corporate farms compared to small-scale farmers, one questioner asked whether governments 'should get out of the road of big investors' who are

more likely to introduce new technologies. In response, panel members said that to encourage private investment, government needs to 'do its homework to provide an enabling environment'; for example, ensuring that smallholders have secure title to their lands so that they will not be compromised by foreign investment. Government investment in rural infrastructure and extension is crucial to the generation of win–win outcomes. Government cannot simply get out of the way: it has an important role to perform. Policies or programs to encourage fertiliser use where it is needed and to discourage it where it is being over-used were also suggested.

One presentation had shown that yield outcomes on research stations might be very high while actual returns on farms were sometimes orders of magnitude lower. One questioner asked whether this was a failure of research or of extension. In response, panel members said uptake of known technologies is 'one of the most intractable and complicated issues'. Farmers often do not use technologies for very good reasons and they need to be convinced through sound top-down and bottom-up communication from trusted sources, such as plant clinics and fellow successful farmers or 'local champions'. Farmers have to have 'a real reason why they should adopt' a new technology or farming practice.

The same applies to adoption of recommended policies: policy makers need to understand and be convinced of the benefits of new policy approaches through research, consultation and advocacy (but not with a loud hailer). IFPRI had some success in enabling policy change in China, Vietnam (where the program had been supported by AusAID), Bangladesh and Ethiopia.

A related issue was how we measure the performance of researchers: whether by the number of research publications in peer-reviewed journals — an important measure of quality — or by eventual development outcomes including through an integration of new, higher yielding varieties and agronomy and 'reaching farmers at their scale'. In the CGIAR Consortium, the emphasis is changing from the former to the latter, although definition of expected development outcomes needs more work.

One questioner from the floor asked whether there was an imbalance in the international agricultural research investment between genetics and crop management. Rijsberman rehearsed changes that were taking place within the CGIAR Consortium, which is now built around 15 programs. Of these, seven focus on crop or livestock improvement and three focus on farming systems. The CGIAR has been recalibrated away from what some saw as an excessive focus, in the past, on crop improvement to a more balanced set of research programs today.

Impact assessment

Impact assessment is critical to continued investment in international agricultural research, and healthy debate around returns — such as takes place within ACIAR — is to be welcomed. The rates of return to investment in international agricultural research are high, but are they 'too good to be true'? There can be 'no doubt' that there are high rates of return from investment in

research projects, as found in many analyses of impact; but these might have to be moderated by the costs of 'dry wells of research' that yield less easily measurable returns or no apparent returns at all.

A mix of high and lower (or absence of) success is in the nature of research, so that we should be cautious in any claims of blanket success, and evaluations should be done 'at the portfolio level'. Venture capital investors work on a success ratio of 1 in 10. Nevertheless, specific interventions, even if they are few in number, could often yield benefits at the level of 'billions of dollars' that easily justify investment in the system as a whole, even if unsuccessful projects outnumber successful ones. Research that identified and led to the control of the cassava mealy bug was cited as an example of a project that yielded massive returns. Another was the return to CIMMYT's and IRRI's estimated $30 million investment in semi-dwarf varieties of wheat and rice research in India and China which, in the recollection of one delegate, generated returns of a billion dollars a year. Benefits to other countries including the United States and Australia — the so called 'hidden harvest' — add to the value of the returns, and full costing could moderate return estimates.

Valuing the environment

What values might be placed on benefits to the environment, wildlife habitat, water quality and so on, in any portfolio evaluation? There were mixed views on this question.

On the one hand, if evaluations are focused more strictly on those 'areas where benefits might be more easily measured' — and the broader social and environmental benefits heavily discounted — the resulting impact assessments are more reliable and defensible. An example put before the panel, of efforts to put a value on the environment or ecosystem services, 'came up with such huge numbers, in the order of $80 billion' they made any comparison with 'the value of irrigated agriculture and all the communities that depend on that, meaningless.' The Natural Capital Project, started by Gretchen Daly at Stanford University and involving the Nature Conservancy and the World Wildlife Fund as well as the University of Minnesota, might provide a model.

Another approach discussed is to place a value at least on certain things and arrange payment from the beneficiaries; for example, the payment by people 'up-river ... to maintain the forests or agriculture' or to enhance supply for urban water-users downstream.

On the other hand, it is arguable that we should not worry so much about the dollar value of ecosystem services but place greater emphasis on values and the value that people place on the landscape that is essential to all things: the numbers of people who benefit, the volumes of water not being mined out of a watershed and so on, without attempting to monetise the benefit. Various parts of the landscape contribute to more than one thing: not just the commodity throughput but also human welfare and the planet's well being.

A practical way forward would be to take ecosystem services into account in landscape planning. Releases from dams, which are often designed without taking into account wetland or fisheries values, can, it turns out, through re-

engineering or management practice help sustain fisheries or maintain ecosystem values. CIFOR, for example, has started looking seriously beyond the 'direct provisioning services of forests such as fruits and bush meat' to what might be described as ecosystem services — water filtration, pollination and so on.

By considering landscapes, including urban components and areas undermining exploitation, in an integrated way but not necessarily comprehensively, it may be possible to recognise that parts of the whole feed off and render services to each other. This approach might not come up with 'one grand number' or value, but it might work.

The balance is difficult to strike. Overall, an integrated or selective systems-approach commends itself. Finally, however, there is another dilemma: by placing too high a value on ecosystem services, which might be a tendency amongst the rich, you face the risk of undervaluing food, upon which the poor and hungry place a very high value.

Urban–rural interaction

Noting that many speakers had touched on the theme of integration, one questioner asked about the question of funding: where would you go to gain funding for a research proposition that crossed sectoral or silo boundaries? The question has general application but is particularly relevant to the urban–rural interface.

The problem is, one panel member responded, that funding of such research was 'nobody's business'. How do we preserve agricultural land and at the same time take advantage of urbanisation, which is a fundamental driver of focused demand for food production that can enhance the profitability of peri-urban or nearby agriculture? The same considerations might apply to agriculture and mining. Another driver of urbanisation is the relatively high prices that farmers or communities can gain from the sale of farmland.

The issue is critical. By 2040, the majority of the world's people will live in urban areas. Any food system has to reflect the increased demand of an urbanised world for healthy, nutritious and safe food.

Nutrient recycling

Another dimension of the rural–urban interaction is that people are 'living and consuming' in the cities. As a consequence, nutrients in harvested products are being transported from rural or peri-urban domains through these consumers into the formal or informal sewers of the cities, and are accumulated or flow out into freshwater systems. Can nutrient recycling, in some way, reverse this lose–lose phenomenon into a win–win one? Should we be placing a value on sewage?

One panel member responded by reminding participants that 'by far the most challenging millennium development goal is the one on sanitation'. His primary goal when he worked with the Gates Foundation was to try to come up with a way to deal with waste that recovers the energy and nutrients within it, and return them to agriculture. In response to a question he said he had funded several projects at the Gates Foundation that looked at the role of biochar as a means of burning sewage and generating energy but in the process 'generating

a stable carbon with the nutrients embodied, particularly phosphorus and potassium'.

Increased food prices — a good or a bad thing?

A questioner from the floor recalled that food prices had kept low for two or three decades towards the end of the 20th century. Farms in food exporting countries had remained viable only through increasing the efficiency of production. Farmers will respond to increased demand and to higher prices for their produce, and from that perspective an increase in grain prices in particular was overdue. Increased prices would lead to increased production.

A panel member agreed that higher food prices could also be good for smallholders in Africa and in south Asia to increase their incomes, but only to the extent that they can gain access to seed, agricultural services and markets. Exports from the major grain producers such as Australia, the United States and Brazil can contribute only a fraction of the world's food needs, and an increase in the global price would not be good for all.

Oil price increases

One questioner, whilst complimentary of most of the presentations at the conference, said 'just about everyone had ignored the question of rising oil prices'. If as was forecast the price of oil reaches $180 a barrel, the consequences for agriculture could be very serious: 'a farmer in Australia can spend $150,000 a year on diesel alone, just getting a crop in and transported'.

Dr Shenggen Fan agreed. Increases in energy costs kept 'food or agricultural economists awake in the evening', he said. He referred to a correlation of figures in his presentation, which show that as oil prices go up food prices do the same. One factor in this correlation is subsidised biofuel production because of the biofuel mandate in Europe and the United States. But even without the mandate and the accompanying subsidy (which would not be needed once oil prices pass a certain point), biofuel production will become economically profitable. Farmers in developed and developing countries who have available land will benefit, but the impact on the poor of higher prices, driven in part by the demand for grain for biofuel stock, will impact badly on poor consumers, especially those who spend some 60–70% of their income on food. This is an area where we needed to think of potential government intervention.

Population

One questioner challenged the panel to discuss the question, too often ignored in her view in public forums, of population growth. Panel members responded by suggesting that population *per se* was no longer the key problem for food security at all; instead it is the 4 billion people already on the planet who were living longer and the proportion of them who were trying to emulate our diets. As one panel member said, 'two-thirds of the problem of future food production comes from the increasing waistlines of people who look like you and me'. He said there are 'a whole bunch of other people who are trying to do what we do', and it might be 'unfair to point to the developing world and say population is the problem'. In the view of at least one panel member, 'It is not'.

Hon. John Kerin AM, Chairman of the Crawford Fund, closing the 2012 conference.

There is still a lot of work to do on family, without question, the panel said. However, the big question we now face is not the population bomb but the prosperity and consumption bomb, and, in some cases, the concomitant growth of diseases such as Type II diabetes.

Market failure

In a question which he self-characterised as 'outrageous' the facilitator asked: given the numerous failures of administrations to translate fine policy intentions into effective interventions, would it not be better to leave much more to the market? Responses from the floor and from the panel included the slow impact of market corrections, and the view that the market cannot operate without an appropriate set of conditions (or a policy framework); for example, without conditions under which you can have private seed companies there will not be a market in seed companies; and getting seed companies to replace government extension systems requires intervention. A key reason for market failure, or the inability of markets to act freely or perfectly is the absence of perfect knowledge. To think through the value chain and 'how farmers can be connected to the market' is also key.

Conclusion: Is there cause for 'Malthusian' optimism?

Perhaps the last word might be left to Jonathan Foley. In his final comments on the day he said:

> *I've come out of this meeting with a renewed sense of optimism, seeing evidence at this event of the incredible array of work happening in a diversity of areas: a breakdown of the old dichotomies between agriculture and the environment; between crop genetics and crop management; between forests and surrounding landscapes; between urban and rural interests. There is an encouraging recognition of a continuum across a lot of different sectors.*

We've seen that the participants have created opportunities for leveraging a very big global problem and some of the biggest challenges civilisation has ever faced. We've seen many more new opportunities by bringing together different disciplines, than ever we've ever had before. We have come up with potential solutions and that makes me very happy and hopeful today.

Dr Denis Blight AO, the Chief Executive of the Crawford Fund, has had a career including positions as an Australian diplomat, public servant and chief executive. His association with international agricultural research began in earnest some 25 years ago. Prior to working for the Crawford Fund, he was Director-General of CAB International, an intergovernmental body in research, training and publishing in the life sciences, and had 15 years with IDP Education Australia, the international development program of Australian universities and colleges, including the position as Chief Executive.

Email: denis.blight@crawfordfund.org

Q&A sessions*

Moderators: Dr Denis Blight AO (Tuesday)
Professor Shaun Coffey (Wednesday)
Panels: The conference speakers on each day

Tuesday

Moderator *(Denis Blight)* My name is Denis Blight. I'm the Chief Executive of the Crawford Fund, and was the CEO of CABI preceding Trevor Nicholls. After I'd left, Trevor invited me to write a history of CABI which turned 100 years old in 2011. One story I came across included a quotation from the Reverend J.G. Gibb. He said, in about 1842:

> *All of God's creatures have a purpose; all of God's creatures have a virtue, except for the weevil. That it has virtues there can be no doubt; it is just that they are deeply hidden.*

CABI actually unveiled one of the virtues of weevils. Asked to find the pollinator for the oil palm, CABI's identification research discovered that it was a weevil. When oil palm was first introduced to SE Asia it was introduced without the weevil, but based on CABI's research the weevil was transported safely, with all appropriate tests, to Malaysia and a booming industry resulted. This booming industry has latterly been blamed for many other ills in the region, so I'm wondering if this actually was a weevil or an evil! Now let us begin this Q&A session.

Q. *(Peter Carrbery, CSIRO, to Jonathan Foley)* Thanks for the nice presentation. You presented five scenarios as essentially solutions to future food demand and I hope I'm not misquoting you but it was somewhere around your third scenario that I think you said: 'It's simply a matter of deploying currently known practices'. Yes, that's true, if you ignore the social, cultural, institutional, political constraints. Should you not present those scenarios with some likelihood term or probability of being able to overcome those constraints along with the simple biophysical perspective?

A. *(Jonathan Foley, University of Minnesota)* Yes, that's a very good observation. You're absolutely right. What I was trying to point out is that there are biophysical realities which, although people like to ignore them much of the time, tell us that, yes, we can actually deliver twice as many calories by 2050 and dramatically reduce CO_2, methane emissions, biodiversity losses and all those things, as I mentioned — and it's just a 'simple' matter of reorganising human civilisation. Obviously it's not simple, and so, you know, there's a bit of tongue in cheek here. In my 20 minutes I was outlining the broad opportunities. I think the point also is that a lot of the narratives we're currently using, about what

*The Q&A sessions were recorded and transcribed for inclusion in these Proceedings.

Denis Blight (left) and six of the panel (Jonathan Foley, Frank Rijsberman, Shenggen Fan, Christine Padoch, Xuemei Bai and Trevor Nicholls) listen to a question from Prof. Andrew Campbell, live videoed in the audience. The other Tuesday speakers were also on hand to answer questions (not in picture).

we need to do first, are still incorrect and not really informed by biology or physics either. A number of us are pointing out that soil nutrition is a very big area that deserves more attention than it's getting; or that water efficiency and productivity is a dramatically important area; or that genetically modified crops may not be needed in fact for food security but are useful for farmer income. And so I think the science, even though it does make it look like everything else is easy, gives us a road map to where we should be putting our priorities.

Also at the end I showed maps that tell you, if you really want to try and tackle climate change in agriculture, here are some starting points based on, again, the biology and the physics. So I agree, yes, I've given short shrift to all the economics and policy issues, because of the time constraint. I realise those are not simple issues, but I hope that science — the biology and the physics — can help point the way.

Moderator (*Denis Blight)* Does any other panel member want to comment on that question?

A. *(Frank Rijsberman, CGIAR)* I used to work at IWMI, the International Water Management Institute, and there many people used to point out that it was 'simply' a matter of introducing well known technologies. They kind of overlooked the fact that farmers often didn't use those technologies, for very good reasons. So you know, adoption of known technologies is one of the most intractable and complicated issues. That's just a little aside.

Moderator (*Denis Blight)* It's a bit like adoption of policies. Shenggen, you outlined a series of policies for governments to adopt. Is it as simple as that?

A. *(Shenggen Fan, IFPRI)* Well this is a research topic by itself! I think the capacity to demand policy research is also very critical. So policymakers, politicians, need to understand, need to appreciate different policy options.

Moderator (*Denis Blight)* You've had some success in working, for example, with China where we've seen quite radical change in policies, I think it's fair to say?

A. *(Shenggen Fan, IFPRI)* Well in addition to China we also had some impact in Vietnam, in Bangladesh, in Ethiopia. In Vietnam the program actually was partly supported by AusAID.

Moderator (*Denis Blight)* Trevor, I think you also referred to the adoption question in your presentation.

A. *(Trevor Nicholls, CABI)* Yes that's right, getting adoption of new methods is not an easy matter. Part of it is communication but another part of it is giving people a real reason why they should adopt them — not because they are a good thing but really communicating what the benefits will be, in terms that are relevant to people. We've certainly found with our plant clinics and 'Plantwise' that we needed top-down *and* bottom-up communication to attract users. We needed local champions on the ground but we also needed to work at a senior political level to have those clinics accepted as part of national policy and part of the broader plant-health system. Otherwise they're just another interesting intervention by NGOs or donors or someone like that. You have to achieve a broad integration into the system and an ownership by the national system to make the adoption happen.

Moderator (*Denis Blight)* Why don't we just leave it all to the market? I mean what makes us think that governments and policy makers are any wiser than the market? My experience is that government intervention can often be counter-productive. So the sort of policy solutions that Shenggen Fan and all of you are recommending, really, when adopted by government, get translated into legislation, get translated into meeting the sort of political balance required in their country, and end up being so compromised that nothing happens. Wouldn't it be better just to leave it all alone?

A. *(Frank Rijsberman, CGIAR)* Sometimes the policy advice that Shenggen Fan would give is to actually create conditions in which the market can really function. If you don't have conditions under which you can have private seed companies then there won't be a market in which you have seed companies. And actually getting the seed companies to be a viable alternative to government extension is of course a key area of our work. To think through the value chain, how farmers can be connected to the market is a key part of that as well. But isn't that part of the policy advice that we should be providing.

Moderator (*Denis Blight)* John Kerin do you want to comment on the competence of governments?

A. *(Hon. John Kerin AM, the Crawford Fund)* Well governments muddle through. If you look at Australia's position with respect to markets, we see that markets do work but it often takes a long time for them to work. What you need to analyse is market failure, market power and market behaviour; and the confounding factor is, of course, that you can't have really freely acting markets unless there's perfect knowledge.

Moderator (*Denis Blight)* Daniel Rodriguez you had a question which is related to this discussion on adopting techologies. I think you gave the example of IRRI: the contrasting figures we saw for IRRI inside the gate and rice grown outside the gate of IRRI.

Q. *(Daniel Rodriguez, Queensland Alliance for Agriculture & Food Innovation, the University of Queensland)* My question has almost been answered already, but still I was impressed by these differences you had in production of rice between the experiment station at IRRI and outside the station, outside the gate. One was 28 t/year; the other was 8 t/year. I was wondering: what causes that failure? It's related to what we're talking about now, it's a very complex problem. We have a number of technologies, and we know they might work, but how are they going to be adopted? And I was wondering what sort of effort you guys at CGIAR are dedicating to the development of the different agendas: for example, the breeding or the innovation systems, the development of the innovation platforms that are needed to really develop those connectivities between farmers, markets, businesses and to start the economic growth and economic activity in these places?

A. *(Frank Rijsberman, CGIAR)* Well part of the answer to that question is that at IRRI they're showing what is physically feasible but they're not trying to make money. At the low rice prices that we had until recently, I was living in Sri Lanka, and there was virtually no rice farmer who could afford to be a rice farmer. Most rice farmers were part-time rice farmers and making their money somewhere else. So under those conditions they had no incentive to try and optimise their yield. That's a key part of the situation.

It's also true that until recently in the CGIAR, while I was at IWMI, after seven years we had an external evaluation. A bunch of academics, some from Australia, came to evaluate IWMI's results in terms of the number of publications per scientist in high impact journals. That was, then, the primary way of evaluating researchers in the CGIAR, and it has since changed very significantly. The CGIAR research programs that we now have, and the views of our science council, will be held accountable for reaching development outcomes.

What are those development outcomes, and how can we move from research outputs to outcomes — which are somewhere in between research outputs and the final impacts? Well I always define them as the proxies for impacts that the investors can easily see to make it worth investing, but close enough to the research outputs that we can hold the researchers accountable for delivering them. It's not an easy task to come up with what those outcomes are: the partners, the countries and the CGIAR need to come to an agreement about the development outcomes that the CGIAR should deliver. But at least I can reassure you that that is now at the heart of the agenda. So five years from now when we have external evaluations we'll still count numbers of publications, but it will be more as a quality-control mechanism, and we'll be held accountable for delivering development outcomes. And very deliberately, in addition to the crop improvement programs, we now have challenge research programs like the one Dr Sanginga was speaking about earlier — the systems programs which

are focused on farming systems. There we try to integrate the varieties and the agronomy. The outcomes that we'll achieve there are definitely focused on reaching farmers at their scale, and demonstrating an impact, which is much closer to the kinds of things that Trevor was talking about before than what you're used to expecting from the CGIAR.

Moderator (*Denis Blight)* Do you want to comment on that Dr Sanginga, because you did make some point about that in your presentation?

A. *(Nteranya Sanginga, IITA)* Yes I would agree with Frank. And talking about adoption, I see this research as a platform where you have all the actors, whether in the private sector or the public sector, playing their roles and you will see adoption passing from a maximum of 20% up to 40% in some of the countries like Rwanda, Uganda.

Moderator (*Denis Blight)* And in your presentation you were saying that actually the gap gives reason for hope, because we can close that gap and increase food production?

A. *(Nteranya Sanginga, IITA)* Absolutely. Just remember that around 20 years ago we couldn't even talk to the private sector or talk even to the government. We were just doing this kind of linear research, and that's really changing tremendously now.

Q. *(Tony Fischer AM, the Crawford Fund)* Getting back to the subject of the seminar, one thing corporate and large-scale investors ought to offer is a very easy route to the adoption of the best technology. And this is the argument that people like Collier at Oxford University put forward, that the way to really move things in Africa is to get out of the road of the big investors. What does the panel think of that?

Moderator (*Denis Blight)* Dr Sanginga, the question is should governments (I think you mean governments?) get out of the road of the big investors because they're more likely to introduce the new technologies?

A. *(Nteranya Sanginga, IITA)* Well I believe, and I want to be frank here, that the government in Africa has a role to play. These kinds of policies in the 1970s and '80s from the World Bank about structural adjustment almost killed African agriculture. What we see now is that the new leadership in Africa is trying to reverse that, and in some situations suggesting even going to subsidies, calling for smart subsidies. We see that as necessary and very important.

Moderator (*Denis Blight)* Do you want to add to that, Shenggen Fan?

A. *(Shenggen Fan, IFPRI)* Yes, I truly believe that the private sector or even foreign investors can play a large role in Africa. However, the government needs to do its homework to provide an enabling environment, rural infrastructure extension system and, more importantly, regulations to make sure that smallholders, smallholder farmers, have the land rights so they will not be compromised when investors come. So truly explore the win–win opportunities. The government cannot get out of the way of investors; it has work to do first. That's actually related to one of the previous questions, what government

can do. Markets sometimes fail, so government's job, first, is to make sure to correct market failure. Second, it is also to make sure that certain policies and interventions have ideal design distribution outcomes to help the poor, because the market cannot help the poor and you need public intervention to do that.

Moderator (*Denis Blight)* Now, the next set of questions relate to return on investment in international agricultural research. The first question, from an unidentified person, is essentially the one asked by you, Frank: Is this all too good to be true? I'm looking for Ron Duncan in the audience. I'm not suggesting that he's the person that asked the question but he might help me here. Ron, is it too good to be true? Would you like to rephrase my question?

A. *(Ron Duncan, the Australian National University)* Thanks very much for putting me on the spot Denis! The internal rates of return that a lot of the analysis of impact leads to are extremely high, and one has to wonder whether all the costs are being counted and also whether the appropriate values are being put onto the benefits that are supposed to flow from these projects. But it is true that research is of a nature where single successful projects do have very large rates of return; and it's true there are a lot of 'dry wells' in research and that the really successful projects are needed to pay for the dry wells that researchers dwell in. So my belief is that we do have to be cautious about these high rates, but there's no doubt that there are very high rates of return associated with some research efforts.

Moderator (*Denis Blight)* Frank, you're the one that made the statement. I'll ask you to comment and then I'll ask Shenggen to comment on that.

A. *(Frank Rijsberman, CGIAR)* Well if we were a private company and we did our marketing here, you might say: 'Oh you know these are your numbers, we don't believe you'. But in this case all these impact assessments we're quoting are carried out by ACIAR, independently. They have been carried out, I would say, time and again by the World Bank for convincing their own internal decision makers. It's true that when you look inside the box to see what generates these very high returns, it usually is a few very specific interventions, like the Cassava Mealybug. But in fact the Cassava Mealybug generated billions worth of returns, paying not just very high returns for the Cassava Mealybug research but also for all the other hundreds of not very high returning investments as well. So a few of these big hits generate the high rates of return for the system as a whole. And of course there is a fairly high variation; I think I showed that as well. Some studies have quite different rates of return. Impact assessment like this is difficult; it is relatively well-established for crop improvement; very much harder for policy research or for natural resources management.

Moderator (*Denis Blight)* Trevor might help me here, with a figure relating to the private sector. My recollection is that only one in seven private investment proposals work. Is that right?

A. *(Trevor Nicholls, CABI)* Venture capitalists will typically work on a ratio of one in ten. We are much more 'blue sky' than them: we would have only one in every couple of hundred projects, but those are such 'big bang' successes that they actually pay for the others. That's the story.

Moderator (*Denis Blight)* So why can't you run yourself as a business and make profits?

A. *(Shenggen Fan, IFPRI)* When I was a researcher, during my previous life, I did some impact assessment of IRRI research, and its impact on economic growth and poverty reduction in India and China. I remember, just for IRRI's investment every year, the return in China and India was about $1 billion a year and the total investment of IRRI at that time was about $30 million a year. Well obviously not everything succeeded, but just consider the semi-dwarf varieties — semi-dwarf wheat and rice adopted in China and India — that impact was tremendous. In terms of methodology, we didn't discount the future values to today's value or bring back the returns to today's value. I also did another study with Australian colleagues, to quantify again the impact of IRRI and the same research on benefits to the US. We call that benefit the hidden harvest, and that in itself got large amounts of money back from the investment. There is a publication on the IFPRI website called 'hidden harvest' where you can look at the methodology and the data — the concrete methods in calculating returns.

Moderator (*Denis Blight)* Many of these assessments come out of ACIAR so I'm going to ask Nick Austin to defend their reputation.

A. *(Nick Austin, ACIAR)* Thanks Denis for the opportunity to comment. The impact assessment program within ACIAR I think is a critical part of ACIAR's work, for a couple of key reasons. First, it is demonstrating the value of the investment, taking on board the comments of those who have spoken in relation to the numbers. I think that impact assessments are increasingly important, in the context of a growing aid program and growing investment from Australia into international agricultural research, and making the case for that investment. From an ACIAR perspective internally also, they're really important for informing decision-making in interpreting where the best returns or opportunities might lie. There's a healthy debate that goes on within ACIAR around the results of these programs. It might be opportune, in that regard, to mention an external review that our Minister, Senator Bob Carr, has commissioned which was announced last week and following on from the comments of Professor Ron Duncan who is a member of the external review panel. The review panel is chaired by Bill Farmer. The review is at the request of ACIAR. Dr Wendy Jarvie and Terry Enright round out the four member panel. They'll be doing their work between now and the end of December [2012] with fairly broad terms of reference about appropriateness, effectiveness and efficiency of ACIAR's operations and particularly in relation to the effectiveness of the impact assessment program. That series of evaluations now over many years I think will stand us in good stead internally. I mention that because there'll also be a call for public submissions to that review, and given the interest of this audience in that subject we look forward to the input into that review.

Moderator (*Denis Blight)* Are there questions from the floor on this subject of impact?

Q. *(Andrew Campbell, Charles Darwin University)* I agree completely with Nick about evaluating the impact of research. However, just a caution: it's very important to do the review at portfolio level, but if you start using it to drive

investment then inevitably your investment will track those areas where benefits can be more easily measured. Having experience in portfolio evaluation, we used to round down any benefits in wildlife habitat to zero, benefits for water quality to zero, social benefits to zero, because we weren't confident in the numbers. Once you do that then your investments will track those areas where you can get easy adoption numbers and translate them into easy production benefits, and the broader environmental and social issues will be discounted inevitably. So, again, this is just a caution against those evaluation techniques — but that doesn't mean it's not a good investment.

Moderator (*Denis Blight)* A question sent in earlier asks how we can learn to include the cost imposed on ecosystem services as a factor of production in agriculture? That will require us first to value those services; and how should we attempt this?

Q. *(Diana Gibbs, Murray-Darling Basin Authority)* That is my question. The MDBA is involved in water-use issues at the moment. I am very interested in what some people see as a trade-off between ecosystem services and agricultural production. I actually see them as being the same thing. I was very impressed by the number of speakers who have talked today about the need to integrate a whole lot of different skills and disciplines in these sorts of issues — which I quite agree with — but when we look at the traditional factors of production for agriculture how can we make sure that we include any loss of ecosystem services as another cost? That brings us to the need to actually consider ecosystem services and how do we value them?

A. *(Christine Padoch, CIFOR)* Yes, well we have actually done very little, so far, in understanding the value of all those systems. At CIFOR we're just starting really to look at it very seriously. We've been looking at those direct provisioning services of forests for families — you know, the fruits and the bush meat and all, for quite a while. But the idea of ecosystem services, and just what forests contribute, is a difficult area. We have the list and I read off the list of some of the services we want to look into: water and pollination and so forth. Some of that is known, but often only in very specific contexts, very separated really from these particular landscapes. I think looking at it much more broadly, and having a landscape view of it, is all important.

Also I think that we're still missing some of the social areas. For instance, how much do forests contribute? For half the year, people depend on those forests, and therefore you do have the labour in these areas, and the labour is supplied to agriculture. I think there's a whole series of areas to look into and to focus on, and this is something we're just starting.

Of course we have to be nuanced about it, and it's not all agriculture in all places at all times. I mean you can grow things in laboratories if you want, but we need to understand under what circumstances there will be elimination or degradation of these services, and who will bear the strongest and hardest impact, where and at what times. I think these are questions we really need to look at. So my answer to your question is that I think we need to make a start and learn to put it in context, and I would suggest we use a landscape approach.

A. *(Jonathan Foley, University of Minnesota)* Well I'd agree completely with what was just said, but I look at this question of ecosystem services as a massive market failure; I mean there's no other word for it. Markets are great if they get the right signals, but if they receive no signals they cannot work. And they're not getting three really fundamental signals. One is, what are the services that you know nature is providing and that have some kind of value? That's huge, whether it's physical climate regulation, flow regulation, water quality, pollination, all the rest, the things we've all talked about today — hugely important. We're beginning to recognise those.

The second, Christine just mentioned: the winners and losers. You know tropical deforestation certainly benefits a few, but many others who are not participating in that part of the market are the losers of that proposition, whether it's from what happens downstream for air quality, massive increases in malaria, what have you.

Third is the confusion of stocks and flows. I think a lot of people have this confusion when they think about economics. Economists like to measure flows but the real world likes to measure stocks, and that's where things get really tricky. We think about capital stocks, whether they're financial capital or human capital and natural capital. We're liquidating the natural capital of this planet and thinking it's profitable. That's insane. To liquidate the Ogallala Aquifer in the United States, or the topsoil of a region, or biodiversity, whatever. I mean the fact that we can consider that 'economic' shows just how insane we are. It's a massive market failure that needs to be remedied.

Q. *(Michele Barson, DAFF)* I'd just like to comment on the ecosystem services issue. I think there might be a much closer relationship between ecosystem services and agriculture than perhaps many people have been thinking about. Of course production of food and fibre is a provisioning ecosystem service in itself, and in the work that we've been doing over the last few years through Caring for our Country we've been encouraging farmers to improve the nature of the land management practices that they adopt for several reasons. One of them is to encourage production benefits which of course everybody is looking for, and the other is to encourage the improvement of soil condition to give benefits to the broader community through the quality of the ecosystem services that agricultural lands provide. I wonder whether any of the speakers have actually done any work or thought a great deal on the nature of and the benefits that agricultural land provides to the broader community?

Moderator (*Denis Blight)* Just before you answer that question can I go back to the earlier question. I heard that the Murray-Darling Basin Authority had actually tried to do some evaluation of ecosystem services and gave up because it was too hard? Is that right?

A. *(Diana Gibbs, MDBA)* It is certainly a very important political question for Australia. We did try; we've tried several studies and that was the basis of my question: I am looking for some guidance. I quite agree with Jonathan — you know we've been mining our natural resources, particularly during the drought, and we should include that as an externality in our production. Yes we tried to

value environment, or ecosystem services, but the work we did came up with such huge numbers, in the order of $80 billion, and we were trying to compare that with the value of irrigated agriculture in the Basin and all the communities that depend on that; it just became meaningless. I'd be very happy to correspond with any of you about how we resolve this issue.

A. *(Jonathan Foley, University of Minnesota)* There are a number of groups now where economists and hydrologists and ecologists are collaborating to do that kind of work. One I'll just plug is something called the 'Natural Capital Project' which was started by Gretchen Daly out of Stanford. Our university's part of that, as are the Nature Conservancy and World Wildlife Fund, and that project's been pretty influential in trying to get really good science in that area, but I'm sure there are a lot of great Australian groups working in a similar area. So I can't answer that specific question.

For the other question, I guess really Christine could answer it better, but part of the question was about, maybe rephrasing it, as opposed to thinking of ecosystem services and agriculture as some kind of dichotomy that you're trading ecosystem services off for food production. I think what Christine showed, and she should say this but others have too, is that it isn't a dichotomy; that it's a continuum of portfolios managed through different kinds of things. And so if we think about agro-ecological approaches that are managing for more than one outcome, not just commodity throughput but also human wellbeing and the landscape wellbeing as a whole, that we could come up with some quite different kinds of situations that I think will be very beneficial.

Moderator (*Denis Blight)* It seems to me this is a pretty vital question; actually it is quite relevant to the research topic of land and resources, provided we express it in non-emotional terms, evidence-based. Shenggen?

A. *(Shenggen Fan, IFPRI)* In fact, yes, there is some work by economists to measure the value of the eco-services, using different scales: global, national and the micro level. But here I want to emphasise that this value also has huge distributional consequences. So if you put too much value, higher value, on eco-services by very rich people, that will in fact not support people, poor people who will not have access to food, will not have access to certain income opportunities. So we need to look at that trade-off.

A. *(Frank Rijsberman, CGIAR)* Well one thing is evaluating or valuing the ecosystem services, but that might be hard. There's also the practical approach of just taking them into account. A lot of dams were built for hydro- or for irrigation and did not take into account the wetland or the fishery values and so on. And it actually turns out that we might be able to put a value on all those other services. But actually optimising for different functions, there is a win–win if you just realise that some releases from dams can actually help sustain part of the fisheries or can maintain ecosystem values. Even though we can't put a dollar value on them it's quite possible to manage, or re-engineer if you like, management schemes of dams to get higher total value.

Moderator (*Denis Blight)* OK. One question from the floor, then I'll go to Trevor then I'm going to move on to another topic.

Q. *(Campbell Davies, CSIRO)* It's just a comment on the original question. I think if you're trying to value those things in the context of an economic optimisation, which is essentially what was done, as I understand it, in the Murray-Darling Basin, then it will lead you to difficulties because there'll be disputes about the dollar values put on individual components of the system. There are approaches that are more about identifying the values or objectives — the things that people want from those services — and ways of analysing those in a broader systems context that allow you to identify integrated management strategies and the like, which I'd suggest would be a more productive path to go down than trying essentially to do an economic optimisation on a complex system.

Moderator (*Denis Blight)* I see a couple of hands coming up, so clearly this is a question of broader interest so I will dwell on it. Christine, first.

A. *(Christine Padoch, CIFOR)* I just wanted to add, there are schemes where payment is made for environmental services. They don't value everything but they value certain things and then people who are up-river make payments to maintain the forests or agriculture of whoever is down-river: urban areas or whatever. On a broader level, I'm an anthropologist you know, and I thought economists could come up with a magic number for the value of eco-services, and I've been sorely disappointed that they don't or can't do this.

I would like to also argue for the landscape as a basis: looking at the various parts of landscapes as being integrated and feeding off each other and giving and rendering services to each other. That might be a particularly good way to tackle this, but one grand number is probably, unfortunately, not what we're going to come up with.

Moderator (*Denis Blight)* Jonathan?

A. *(Jonathan Foley, University of Minnesota)* Well just to reiterate this point, I wish people would not worry so much about the dollar valuation of ecosystem services, as Frank and Christine have said. I know economists don't like to say it but we make this stuff up. My point is, we can look at valuation in other terms than just dollars or Euros or whatever, and begin to think about this in terms of number of people who have benefited, number of people transitioning to a better life or to the number of cubic metres of water we're not mining out of a watershed. And those things are going to have tremendous real value. The problem with ecosystem services isn't the fact we can't put a dollar figure on it. That's a problem with the dollars, it's not a problem with the ecosystem.

Moderator (*Denis Blight)* We better move on to another subject now.

Q. *(Basant Maheshwari, University of Western Sydney)* My question is related to urbanisation. Peri-urban areas are quite important globally in terms of food production. Urbanisation involves having more hard surfaces, and that's impacting the water cycle. Yet on the other hand we need to house more people. Developers see this as an opportunity to make more money, big money, and farmers, also peri-urban farmers, want to sell the land because they can get a lot more money. And so my question is, is there any hope to preserve agriculture and continue producing food in the future in peri-urban areas?

Moderator (*Denis Blight)* I'm going to ask Xuemei Bai to answer that question first, but before that there was another question from Andrew Campbell on this same, or related to this, subject. Do you want to vocalise that now Andrew?

Q. *(Andrew Campbell, Charles Darwin University)* Just on that theme of integration. Many speakers have talked about the need for more integrated approaches and yet a lot of research investment is still siloed. And so how can we have a more integrated approach? I'm not aware of anywhere you would go for funding to do work across the urban–rural boundary or urban and agricultural planning. As a researcher, where would you go to get that sort of stuff funded? I'd welcome comments on that (as someone who used to run an outfit that tried to do integrated research and got abolished).

A. *(Xuemei Bai, the Australian National University)* Yes, I'll start from the second question. I would like to put the question back to the funders, who are sitting here actually. Because when we are trying to address something that is interactive, between urban and rural, that systematic kind of view, it's basically the business of nobody. So if you go to the urban centre they say, 'Oh that's agricultural business', and then the agricultural people they're only interested in how to improve their productivity. It's really hard to make the case that actually they are all connected, and that if the level of urbanisation increases there's a positive impact as well, as some of our data shows, in terms of green production, crop production and yield. But it is really very hard to make the case to look at both sectors together.

So I think this is a really good opportunity to put this case forward here, because we do have lots of international funders as well as national funders present.

Coming back to the first question, about increasing urbanisation and the need to preserve agricultural land and whether there is any hope. This is a big question to answer — and it is very hard to answer it. The Chinese governments have been trying very hard to preserve agricultural land, but they have so far been failing because there is a very strong fundamental driver that drives local government to sell the land so that they can get profit. Unless you can fully understand those sorts of underlying mechanisms and drivers, and why those sorts of things happen, it is really hard to do anything to preserve the agricultural land.

The Chinese governments have two policies, one to enhance urbanisation for the sake of economic growth and the other to preserve agricultural land. Those two policies they actually are fighting each other. It's all coming from the same government, and people don't recognise that there are these conflicting kinds of policies that are coming from the same government. So I suggest that we really need to start from a systematic approach: try to understand the linkage and then try to adopt more holistic and integrative approaches to preserve land as well as provide enough space for people to live in cities.

A. *(Andrew Noble, IWMI)* Can I just make a comment with regard to this interaction between urban and rural or agriculture? From a practical point of view, today, if you look at where people are living, they are living in the cities and they're consuming in the cities. The biggest challenge we have is that this

is where all the nutrients are being concentrated. I think one of the challenges we have as scientists and as society is how we close the nutrient loop between urban centres and getting those nutrients back to the agricultural lands whence they came. And I think it's clear that there needs to be considerably more research into the interaction between these two spheres, if we are going to address some of the critical water issues that we have and pollution issues that will eventuate with large cities.

Moderator (*Denis Blight)* Give me a practical example of what you might do. The nutrients in western societies end up in the sewerage system don't they?

A. *(Frank Rijsberman, CGIAR)* I thought Andrew was going to talk about a rather interesting group at IWMI working on peri-urban agriculture, because those nutrients where they end up is in the sewer. Next time you go to Africa or Pakistan and you have a salad in your hotel you'll be having those nutrients because people grow vegetables with raw sewage. It's a wonderful way of capturing some of those nutrients. It's not necessarily safe for your health but it's a very big deal in almost every city. Every city, however it grows, always has a peri-urban area, which might displace some of the more regular agriculture but it will always keep a band of pretty active agriculture around it.

Moderator (*Denis Blight)* I thought you were talking about something more radical than that though Andrew?

A. *(Andrew Noble, IWMI)* I think what we should be looking at is resource recovery business models that actually start to look at this waste or put an asset value to this waste. That could essentially address some of the challenges that you have with regard to food safety, as well as generate very large incomes. And I think it requires essentially a social change, a change of behaviour in how we see this waste.

Q. *(Eric Craswell, the Crawford Fund)* I just want to make some comments along the lines of Andrew's point. There used to be an organisation called IBSRAM* which worked on peri-urban agriculture and nutrient cycling in West Africa, particularly in Kumasi, Ghana. And if you think of China and some parts of India as being nutrient-rich areas, rural areas, and cities, in West Africa you've got all of this transport of nutrients in harvested product to the cities and the opportunity to return it into a nutrient-poor rural environment, where it has some real benefit economically.

At the other end of the scale, in the nutrient-rich countries, the cities accumulate nutrients to the point where they flow out into the fresh water systems and out into the oceans, cause red tides and so on. And I know Jonathan captured this issue of the use of nutrients in Asia as being prolific and in Africa as being very limited — that's been discussed. But I think within a country, the rural–urban divide in terms of nutrient availability is something else to consider. That's just a comment.

Q. *(Snow Barlow, the University of Melbourne)*. This is more a fundamental question to all the panel but particularly to the economists. We've heard arguments for

* International Board for Soil Research & Management

the power of the market, and we can all agree with that at times, but for land — and you could include water — where you are looking at an irreversible change in terms of, let's say, good crop land around Shenzhen for instance (and there are many other examples), does economics work here or do you have to go to regulation? And this applies I think broadly to our use of land, water and air across the globe.

A. *(Shenggen Fan, IFPRI)* Well firstly I think that the land rights should be secured: who owns the land? who has the rights to access that land? More equitable access, smallholder access, to that piece of land is so critical. Then you need the market to work, on either rental markets or in the situation now where lots of land are undervalued or grabbed by local governments rather than by the foreign investors. The biggest land grabbing usually happens domestically, by the local governments, by the local community, or by chiefs. In Africa it's more by chiefs, though the whole village is supposed to own that land; usually it's the chief who makes a deal with a foreign investor or with other domestic investors. And in Vietnam, China, it's local government that converts the agricultural land into commercial land and gives a very small amount of compensation to farmers. So yes, the government has a very large role there, to regulate that, to make sure that everybody has access to land, to make sure that the market works, and that nobody can monopolise it. I actually believe that there are great opportunities for everybody to really maximise the benefits.

Moderator (*Denis Blight)* OK. Just backtracking briefly, Frank, can you put some numbers on the importance of recycling sewage, maybe just in the case of one country?

A. *(Frank Rijsberman, CGIAR)* Yes. By far the most challenging millennium development goal is the one on sanitation. A couple of billion people don't have access to decent sanitation. As a result, the second largest cause of death of children under five in developing countries is diarrhoea because we don't have a decent way of making that nutrient-loop closed and safe.

My primary program at the Gates Foundation was to reinvent the toilet, and to try and come up with a way to deal with waste which is safe and recovers the energy and the nutrients in it, and to try and find a way to return that to agriculture. Now wherever you have a city you have a sewage plant. And as I first saw in the Punjab where they built a sewer in 1969, the farmers were using that water. Farmers value the water, but of course it's not a safe practice. In Pakistan 23% of all the vegetables are grown with undiluted sewage, and the rest with diluted sewage.

Q. *(Margaret Hartley, the Crawford Fund/ATSE)* Just apropos of that last comment about the sanitation, I'm wondering if any of the research agencies are looking at the role of biochar as a means of burning sewage and generating energy but then generating a stable carbon with the nutrients embodied, particularly the P and K, to put back in a useful form and create stable carbon sequestration? I think it's a great opportunity that isn't being given enough attention at the global level.

A. *(Frank Rijsberman, CGIAR)* That was my previous job at the Gates Foundation. We funded several projects like that.

A. *(Shenggen Fan, IFPRI)* We have not discussed much about biogas production. Biogas production can really help to convert the waste, including human waste, to nutrients to energy. That we probably have not paid much attention to; maybe your toilet can help do that.

I want to come back to the urbanisation issues, the integration between rural and urban areas in terms of food systems, under the new CGIAR, IFPRI is leading a program to leverage agriculture for nutrition and health outcomes. By 2030 or 2040 the majority of the people on this planet will be in urban centres, say in China, India. China's urbanisation will be probably 60% or 70% and knowing how to provide healthy, nutritious, safe food for urbanised populations will be critical. The poor people will also become more urbanised. So we do use an integrated approach for tackling that issue.

Q. *(Felicity Schonk, Scholar, the University of Sydney)* I just wanted to ask, I know it's not strictly an agriculture-related question, but I mean the whole premise of all these problems is the fact that we do have these massive projections for population increase over the next 40 or so years. Why is it — and I'm putting this question out there to anyone — why is it that measures looking at the problem itself, which is our massively growing population — why are they so unpopular? Why is it so? I mean that is something that isn't really discussed much.

A. *(Jonathan Foley, University of Minnesota)* Well I think others can speak to this as well, but as I was pointing out in my presentation, population is not the problem for future food security at all. It's actually the 4 billion people who are trying to emulate our western diets, who are already here in the world. Two-thirds of the problem of future food demand comes from the increasing waistlines of people who look like you and me, pretty much, and a whole bunch of other people who are trying to do what we do. That's a very big problem. I think it's kind of unfair to point to the developing world and say population is the problem; it's not.

There are 2 billion heading our way, but populations grow for two reasons: one is that there are some people in the world who are having very large families still. But the good-news part of population growth is, there's a whole bunch of people who are finally getting to live as long as we get to live. In India, population growth is driven primarily by longevity; people are finally moving from living 40 years to now living to 75. That's a good thing. So I think we have to be very careful about saying population is the problem. I don't think that it is. I think that it's a symptom of a much larger systemic problem.

You know we had a population bomb that we largely diffused, fortunately, but there's a consumption bomb that nobody's talking about. And we have a modulating feedback on population called the demographic transition. It largely worked; should have worked earlier. There's still a lot of work to do on family planning — no question. But the consumption bomb — the richer people get the richer they want to be — there's no end in sight. So I think we have to be a little bit careful looking at the balance of those two things together.

Q. *(Terry Enright, Crawford Fund*) This question is unrelated to what we were just talking about. It's in relation to food pricing. The spike in food prices in 2007–08

caused some massive problems, but my hypothesis is that food prices have to go up. If you want to maintain production in the developed world, which is where most of the traded grain for instance comes from, these prices have to go up. We've kept food prices artificially low by increasing efficiency of production for probably three decades. So what are the implications of higher food prices? Because I think if we're going to feed 9 billion people we're going to have to have a lot higher food prices to do it.

A. *(Shenggen Fan, IFPRI)* What we are afraid of is high price volatility and the spikes. Say today the food price is high, tomorrow it goes down. Volatility hurts both consumers and producers. Higher food prices could provide an opportunity for smallholders in Africa, in south Asia, to increase their income. However, right now they do not have access to seed, to agricultural services, to markets, and so they will not be able to convert that opportunity to reality. Therefore, right now the higher food prices and price volatility will hurt both poor consumers and producers. What we need to do is convert the higher food prices to certain opportunities for smallholders. Obviously Australian farmers or American farmers, Brazilian farmers, would be very happy to see higher food prices, but what I'm concerned about is the poor hungry people in developing countries.

Q. *(John Angus, CSIRO)* I noticed a difference in emphasis about the direction of research. On the one hand Dr Sanginga made a point that there was a lot more need for agronomic and crop management research; and I think it was Frank who emphasised genetic and genomic research. Is there an imbalance in the research investment between genetics and crop management in the CGIAR system?

Moderator (*Denis Blight)* Yes another question as well, I'll take that and then we'll get the panel to respond, and to make final statements.

Q. *(Jenny Goldie, ACT Peak Oil)* Most of the speeches have been very good but just about everyone has ignored the question of rising oil prices. The International Monetary Fund says that the price of oil by the end of the decade will be about $180 a barrel. This is going to possibly cause economic disruption generally but agriculture as we know it is heavily dependent on fuel. A farmer in Australia can spend $150,000 a year on diesel alone, just getting a crop in and transported. So if we can anticipate possibly a doubling of oil prices by the end of the decade, what are the implications for agriculture? I mean, to me they seem to be huge and yet everyone's ignoring it.

A. *(Frank Rijsberman, CGIAR)* I pointed out two revolutions that I think are going to influence the work of the CGIAR: one is in the life sciences, and glamorous, and I think it will attract new scientists to agriculture because there is tremendous scope for doing exciting and interesting work. The second that I mentioned is what I called the IT revolution, but in fact a lot of that is, well, from mobile phones for extension to precision agriculture — which is another way of saying crop management. It's agronomy for the 21st century, which will have a lot more to do with using that kind of technology, and forms of extension that base themselves on opportunities for new sensors — opportunities for all kinds of exciting stuff.

Within the 15 programs that we have, about seven focus on crop improvement. There are three, one of them that Sanginga described, that are focused on farming systems and one on policy and several on natural resources management. I can't claim that we always get the balance right, but I certainly think that the old CGIAR which was mainly focused on crop improvement has been recalibrated to be much more balanced today.

A. *(Shenggen Fan, IFPRI)* Yes, if the oil price doubles then agriculture and food production will be affected tremendously. Yes indeed, we are very worried about it. That possibility keeps lots of food or agricultural economists awake in the evening. The reason is, when the oil price goes up the food price goes up. You know the correlation of the figures. I showed you the high correlation between oil prices and food prices, for two reasons. One is biofuel production, right now, because of the subsidies, because of the biofuel mandate in Europe and US that really initiated the biofuel industry, the biofuel industry was established because of government support. As oil prices continue to rise, then even without government subsidies and without mandate, biofuel production will become economically profitable. What does that mean? That means food prices will continue to rise. Yes, some farmers who have large pieces of land will benefit. What happens to the poor — the poor who spend 60%, 70% of their income on food? If food prices double could you imagine what will be the impact on their children, on their household members? So we do need to think of government interventions to make sure that higher oil fuel prices will not translate into higher food prices. And there is volatility as well. When the oil price is very volatile, it means food prices will also be volatile.

Moderator (*Denis Blight)* Jonathan, would you like to make a final comment?

A. *(Jonathan Foley, University of Minnesota)* As a final thought … I've come out of this meeting with a renewed sense of optimism, seeing evidence at this event of the incredible array of work happening in a diversity of areas. I think we're seeing a breakdown of dichotomies between agriculture and the environment; between crop genetics and crop management; between forests and surrounding landscapes; between urban and rural interests. We're beginning to recognise that these things are a continuum across a lot of different sectors, which is very, very encouraging. I've also seen that that creates a lot of opportunities for leveraging a very big global problem.

We have talked today about some of the biggest challenges civilisation has ever faced and yet we've seen more solutions than challenges. We've seen many more new opportunities, by bringing together different disciplines, than we've ever had before. And so I feel that while we're seeing some of the greatest challenges that any generations have ever faced in our entire existence we have come up with potential solutions, and that makes me very happy and hopeful today.

Moderator (*Denis Blight)* Thank you very much, and I think that's a good point on which to finish the conference. Thank you all very much for your participation.

Dr Derek Byerlee, Professor Jonathan Foley and Dr Frank Rijsberman during the Wednesday breakfast Q&A.

Wednesday

On Wednesday at the breakfast, Dr Frank Rijsberman, Professor Jonathan Foley and Dr Derek Byerlee reprised the keynote addresses they had given on Tuesday, and then formed the panel for the Q&A.

Moderator *(Shaun Coffey)* I'd like to move into the questions and answers straight away and I invite any members of the House of Representatives or the Senate to take this opportunity to ask the first questions.

Q. *(Senator the Hon. Ian Macdonald)* Good morning. Thanks very much to the Crawford Fund for the breakfast and for the information. My name's Ian Macdonald. I'm a Senator based in North Queensland and my passion, in my long period in Federal Parliament, has been the sustainable development of the plentiful water and good mosaic of good soils across the top of Australia. Most of them didn't appear in the slides, I might say.

My question really is about a disconnect, or a contradiction, in Australia. We feed about 60 million people around the world. We can double that from what we have in Australia. But our farming sector seems to be failing all of the time; the age of the farming community is getting older and older; parents are telling their children not to come onto the land, with a couple of exceptions. Australian farmers are not doing particularly well financially and it's a real concern. We have the ability but it's not being achieved in Australia and I just wonder if any of the speakers have a solution or some way that we can help to encourage people to develop Australia's potential to feed the world.

A. *(Frank Rijsberman, CGIAR)* In many ways the increase in food prices is a mixed blessing. If you are poor, including a poor farmer, and you spend a very large part of your budget on food, then the increase in food prices is, no doubt, a bad thing. But if you're a farmer in Australia, and for some larger farmers in the world where we live, those increased food prices will provide new opportunities, new opportunities for investment, new opportunities for agriculture.

Q. *(John Anderson AO, the Crawford Fund)* The issue of energy security, as Jeremy Grantham points out, the incredible rise in global population centred around, you know, 1800, has really been both facilitated and made possible by cheaper oil and everything that springs from that energy source. Any comments on the implications of probably the end of cheap oil not being far away and the enormous dependence we now have, a quite hopeless dependence really, upon energy to feed ourselves in the future, and what that might look like?

A. *(Frank Rijsberman, CGIAR)* One of my colleagues was asked and answered that question yesterday, so if you'll allow me I'll just summarise his answer. And that is, agriculture has indeed depended on cheap energy and uses energy in many ways. So higher energy prices will cause the cost of producing food to go up. But of course also higher energy prices will mean even greater attraction to invest in biofuels, competing with land that produces food. So, yes, if the oil prices doubled, that would have a major impact on agriculture; it will be an additional challenge for sure. An opportunity for those who produce biofuels probably, but definitely an important challenge for those that want to provide a food secure world.

A. *(Derek Byerlee)* I would also like to comment on the energy and biofuels. I think one of the real surprises in looking at the larger land acquisitions in Africa is how important investment in biofuels has been. And that's partly because African countries have essentially duty-free status in Europe and the US, so that gives them a particular advantage in biofuel production. But certainly, with higher energy prices, that's going to be a major competitor for land, and the real question is, when do we move to the second generation biofuels, which are cellulosic rather than using maize grain or sugar? And even if we moved to the second generation biofuels, which are still going to use land, to what extent is there going to be competition for crops? I think there are some real issues out there, and that if you have high energy prices it's really going to drive this land scarcity issue even more.

A. *(Jonathan Foley, University of Minnesota)* Just to follow up on some of this, one of things that we were talking a lot about yesterday is the ratio of benefits to cost in agricultural systems: how many calories are provided to the world divided by the amount of water, the amount of land, etcetera. But when you look at this in terms of energy, especially petroleum or fossil energy, we see there are tremendous opportunities here; that it's not all bad news; that there are massive opportunities to improve efficiency or to substitute renewable energy sources for non-renewable. So while the peak oil kind of situation or the end of cheap oil is staring us in the face, it is a tremendous challenge; but I think agriculture has a lot of innovation upside to solve that kind of problem, pretty dramatically in fact, probably more than outpacing the changes in petroleum prices. But it's required some very big changes structurally in how agriculture relates to the energy sector.

Q. *(Tony Peacock, Cooperative Research Centres Association)* We had the World Food Programme out a few years ago and Australia did it a big favour by guaranteeing funding for four or five years ahead rather than year by year. Are we doing enough in the CGIAR system with our donor status, and is it enough,

and is there more that we can do that, maybe, wouldn't cost us a lot of money, but would give you more certainty?

A. *(Frank Rijsberman, CGIAR)* Thank you for that question, which plays right into the key parts of the reform. Australia is a very strong partner in the CGIAR, but all the donors together have discussed their normal donor practice. Normally they tell us sometime in October how much they're going to support us for this year, and indeed for 2012, quite a bit of our support is still uncertain. A new reform that I haven't talked much about has brought all the donors together in the CGIAR Fund, just like the senate has been united in the CGIAR Consortium. And the idea is that donors will pool their funds and, if at all possible, will make multi-year commitments.

I'm very proud to say that some donors, like my own country the Netherlands, have just recently decided to indeed pool all their project level funding together, put it into a bigger bucket and make a four-year commitment. If a few more donors are able to do this, and not all of them can, that would be a tremendous help in providing more stability and more opportunity to plan, even with the same level of resources.

Q. *(John Evans, the Australian National University)* My question is to Professor Foley. You made the statement towards the end of your talk about being able to do more with less. But I guess I'd like to have a slight elaboration on that because my understanding would be that generally with agriculture where we run the risk of the most polluting types of fertiliser use, reducing fertiliser inputs there will probably not result in more yield and generally the yield increase is going to be coming from places which are low input.

A. *(Jonathan Foley, University of Minnesota)* Thank you for the opportunity to elaborate on this. What we're finding is again and again and again when you look at the productivity of agriculture in relation to the resource consumption, whether it's per hectare of land, per unit of water, per unit of nitrogen, per unit of phosphate, per unit of energy, that there are about a hundred-fold differences between the most efficient — I didn't say the most productive — the most efficient farmers (that is, looking at how many calories you get per kilogram of nitrogen or per hectare of land or per kilogram of water) versus the least efficient. There's, again, you know, a factor of a hundred difference in efficiency between the best and worst farmers in the world.

For fertilisers, for example, we find the world is in a 'Goldilocks' problem. That is, half the world has too much fertiliser to put on the ground — China, India, the United States in particular. Most of the world has too little fertiliser being used, whether it's organic or chemical inputs. Most of Africa would be in that category. And there are very few who are getting it just right; I think Australia and Western Europe probably come the closest. So, again, there are massive opportunities to grow more, actually, with less fertiliser and less water. It's just a question of being more optimal rather than necessarily just dumping stuff on where it's not being useful.

There are huge, huge opportunities there, and they're much bigger than we think. In just closing these yield gaps whilst still reducing nutrient outflow to

rivers, there's 30% to 40% more food production possible, right there, which is more than all the crop improvement in the last 30 years has given us. It's possible through just changes in land management, and water management as well, as Frank alluded to. Huge opportunities to be more efficient with the land, water and nutrients we already have.

Q. *(Basiita Rose Komugisha, Uganda, James Cook University)* Thank you very much for your presentations. I would like to echo in another way the Senator's question. When I look through this room or the conference we had yesterday, there is a generational gap. We see very old people and the very young. We don't see the middle people in agriculture. I thought it was just in Uganda but it seems like it's the trend. And it's not really a question, but I'm thinking we should think together how are we going to push forward to encourage a certain group of people to come up to do the production, the research to feed the 9 billion people we are talking about. We need to be more aggressive and more eloquent in the way we bring it up. Because as young people when we look at the old people, they are saying they are failing. It's discouraging to go to such a sector that is filled with complaints. So, what strategies do we have in place to have a number of people come up and take the full production issue forward?

A. *(Frank Rijsberman, CGIAR)* Excellent question, and I think it's a key challenge that we face. I mean there are, everywhere, societies like the Crawford Fund, who indeed have been very good at keeping the flame alight, even at a time when agriculture almost fell off the agenda. And yes, let's face it, agriculture wasn't the sexy subject. You know, the number of students in agriculture dropped and dropped. Now I think, partly, having food security back on the top of the agenda, being better funded, having exciting projects happening — they all will help. And I also tried to show you that it's one of the most exciting areas in research. That is on the research side. I hope that the price side will also help attract more people who think of farming as a good livelihood. I lived in Sri Lanka and, you know, Sri Lanka is a rice growing country. But there are almost no full-time rice farmers left. They couldn't afford to be a full-time rice farmer; they called themselves hobby farmers, while their real income came from somewhere else. Now, better pricing will help create better business in agriculture. So we'll need all of that.

A. *(Jonathan Foley, University of Minnesota)* I teach for a living; that's my first and real profession at university, so I'm particularly interested in your comment. But our students have been telling us the same thing, that especially in agriculture at the university the faculty are much more likely to be over 60, white and male than in any other field. And they're finding that it's not really that attractive. There are students, for example, who are interested in the food system, but fewer and fewer people who are declaring majors in agricultural science or economics, because they don't really connect with that faculty. There's a generational divide, as you said so well.

It would be interesting to talk the recalcitrants of our faculty into changing the way they talk about these things, or into even being willing to talk about organics or food systems or local food or urban agriculture. I think we've been blaming the students for so long, but perhaps we on the faculty need to look at ourselves

and say, 'Wait a minute. Maybe we need to change the way we talk about these issues so they are more appealing to younger people and also middle-aged people, to bring us all together to solve these problems, to open these doors a bit wider. It would be tremendously beneficial.'. And that requires quite a bit of change and that's the hard thing at universities, but it will have to happen.

A. *(Frank Rijsberman, CGIAR)* I should have said straight away, yes, we recognise it as a challenge. Totally valid question. I've just visited seven CG centres in the last few months and I was surprised how many young people, how many young scientists, how many new post-docs that are in those centres. A very different situation from some ten years ago. So I think in a way the reprioritisation of agriculture in the last four or five years is already beginning to have that impact.

A. *(Derek Byerlee)* Thank you, very good question. Going back to the land issue, one of the things that really strikes me in Africa, particularly eastern and southern Africa, is that the farm size is declining for the average farmer, yet you have these big investors coming in, taking over large areas of land. That just doesn't make sense. A number of countries, particularly Malawi and Zambia, have set up programs to try to make land available to young farmers. I think the Malawi program has been particularly successful. It's not just making the land available, because they need access to finance and there's also been some very good efforts at developing business skills and new industries for some of these young farmers. I'd be happy to talk to you about it. I think it is a real challenge in South Africa — this emerging young entrepreneurial farmer, a smallholder but a commercial smallholder. And I think it's land plus the other assets.

Q. *(Andrew Campbell, Charles Darwin University)* I agree with Jonathan's analysis about the gap between the best and the average. We certainly have that here in Australia, and then an even bigger gap between the average and the tail. This suggests to me that if there's a hundred-fold difference between the most efficient and the least efficient, then it's not really a research question because we obviously know how to do it. It's an extension challenge, and yet we've hardly talked about extension, planning, incentives, education — which ties into the point from the lady from Uganda. In Australia, in the last week, New South Wales has abolished all its Catchment Management Authorities; we've seen states massively disinvest in agricultural extension. It strikes me that we could waste a lot of money on research if we're not actually trying to get it onto the ground.

A. *(Frank Rijsberman, CGIAR)* Another excellent question. I didn't use the word 'extension' but I think I spoke about delivery, for instance, or our farming systems programs. There is a very deep understanding in organisations like our own that it's no longer good enough to, if you like, come up with new knowledge and publish about it. The new CGIAR is about delivering outcomes with its partners — development outcomes. Yes, there will still be research programs where the staff will be held accountable for coming up with new plans. Dr Sanginga, for instance, at IITA*, his key challenge in the humid tropics is to come up with farming systems that actually help close the yield gap.

---

* IITA, the International Institute of Tropical Agriculture

We probably don't talk about extension because extension in the old way is dead. There are new ways of extension, some of which involve informing farmers and connecting farmers to markets, and others involve helping to create a viable seed industry in Africa. This is not necessarily the big companies that are more interested in working with commercial farmers, but having local, small African seed companies linking their research to farmers, getting the seed to where it's needed. I think that question is very high on the agenda.

A. *(Jonathan Foley, University of Minnesota)* I'd just briefly like to add to that: in the United States my university was founded at the same time as the Moral Act, 150 years ago. During the height of the bloodiest war in American history, our Civil War, we still invented this land grant university concept which is replicated around the world. But we're now in the 21st century, and needing to reboot extension, as we have noted. Probably it needed to end so that something else could come in its place with half the world now living in urban centres, with nine billion people on the way. We're not going to service people very well by driving pick-up trucks to farmers one at a time; it's just too big. But we have a billion people on Facebook right now. This is extraordinary. (And, you know, it makes me very upset to learn there are more people playing Farmville in the world than actually learning how to farm on the internet. That's crazy.)

We can harness these mobile phones and social media technologies and others to amplify what has been known as extension, to a new 21st century model. We heard some great examples of that yesterday, and we need to do a lot more work there. Not just to farmers, but to consumers, to producers, to the Fortune 500 companies, to major investment corporations. These are also huge levers that didn't exist maybe in the earlier days of agriculture and that are now profoundly important actors in the system. We have to reach everybody, not just individual land holders. That's a whole different paradigm.

Q. *(Joe O'Reagain, Fitzroy Basin Association, Central Queensland)* My question's for Frank. With regard to plateaus in cereal crop yields, what are the plant physiological limits? Have we hit a wall with regard to harvest index? Secondly, will the promotion of high yielding crop varieties to the developing world inadvertently put further pressure on already depleted soil nutrients and therefore further drive the issues we've got with fertiliser, as raised yesterday?

A. *(Frank Rijsberman, CGIAR)* The plateauing of yields might be because we are running into physical limits in places like Nebraska. Farmers in Europe and North America and in Australia are pretty efficient already. It's the yield gap in Africa and Asia, where we are very far away from those physical limits, that offer a lot of opportunity, and which need to focus more on extension, on connecting farmers to markets, and also on managing nutrients. Indeed why should we say that in Africa they should have farming systems that don't rely on regular fertiliser that everybody else uses? Clearly we are going to have to use other inputs if we are going to manage fertility as part of that effort to close the yield gap. Yet at the same time CGIAR is a research organisation, and it has people that say, 'What can we do to break through that physiological yield gap?' They are focusing on theory — just like the team at the ANU which said,

'Hey, we'll change the way plants use their photosynthesis process, make that more efficient'. Theorising, they say, 'We'll make C4 rice'. Other folks say, 'We can introduce extra characteristics'. There's all kinds of ideals which at the top level of yield will make a difference, but in the longer term, in the immediate term, when we say we can make an increase it is more about applying non-technologies to get farmers that aren't doing as well as here to do better.

A. *(Derek Byerlee)* I think we don't want to take this plateauing of yields too literally. Tony Fischer is sitting over there; I've been working with him on a book with ACIAR looking at yields and yield gaps, and there's really quite a lot of potential in most countries, particularly in the low and middle income countries, where there are very significant yield gaps. It gets back to a lot of these issues of efficient management of inputs, extension, and so on.

A. *(Jonathan Foley, University of Minnesota)* One of the things that's quite interesting is if you look at these yield patterns, rice and wheat are the ones that seem to have the most pronounced yield plateaus where yields are already high. Those crops receive relatively little investment; we've relied on the public sector to invest in them — only through, let's say, the CG system. They've been ignored by investors in the private sector. On the other hand, maize and soybean yields are not plateauing at all, or nearly as much. That's where the private sector has invested a huge amount of money. Unfortunately those crops are not as fundamental to food security. I think this shows that we need to redouble our investment in the public sphere, so that we level the playing field between the crops that really feed the poor in most of the world versus those that are feeding biofuels and animals.

And so we see the effects of investment and the differential public versus private investment paying off. But now we have about a 20-year period to catch up on so we need to redouble this investment in the public sector for crop improvement, not just leave it to the private sector alone. We've seen what that will do and it's not very helpful.

Q. *(Snow Barlow, the University of Melbourne)* A question to Derek, on the land sector. You mentioned yesterday that Australian land that is available is probably a little cheap or more attractive. Where does Australia sit on the scale of attractiveness for international development and investment?

A. *(Derek Byerlee)* There is an annual report on farm land values around the world. They rated Australia very highly in terms of attractiveness and investment in farmland, partly because Australia's regarded as a low risk country. One country I've been involved in is Ukraine. You cannot buy and sell land in the Ukraine, still. Twenty years after the transition, it's still all on a rental basis. But here you have some of the most fertile soils in the world. Companies are coming in and renting at about $35/ha. That gives you some idea of the differences in the opportunities in terms of land prices. These will yield 4 t, 5 t, 6 t wheat crops if you manage them well. Big differences in opportunities.

Q. *(Elizabeth Finkel, Cosmos Magazine)* Jonathan, you articulated ways we could solve the problem; you said physics and biology show it's possible. And one of the things you highlighted was that 40% of the food we produce is not actually

used for food for people. And then you talked about the 4 billion people who will be looking at the same menus that we've been looking at and wanting to order steak and so on. My question is, what levers can you pull to influence the demands of those 4 billion?

A. *(Jonathan Foley, University of Minnesota)* That's an extremely good question. I wish I had the answer to that; it is one of the greatest challenges. Right now, though, what we're finding is quite extraordinary. For 20–30 years we've been told one narrative, that the only way to get to food security is by improving crop genetics and just leave it at that. We're finding that that's not enough. The yields are plateauing, the investments have not been sufficient and the time lag between what research is doing and what yields actually do in the real world is too long. We're finding that other levers, like diets, like biofuels, etcetera, are becoming maybe even more important to solving hunger than just crop breeding, though we'll need all of these things.

So first it's just an awareness of this issue. Second, we need you to write about this in your magazine and tell people about it. In my country most people have no idea that it takes 33 kg of grain to make 1 kg of extra beef in American feedlot operations. They're horrified when they hear this. We have politicians who are enforcing a biofuels mandate to make ethanol out of corn, even though we have this drought in North America that has hit corn production, causing prices to sky rocket, with the lowest corn stocks in history. This is extraordinarily bad policy from a food security point of view. Again, I think talking about this in the political and public spheres is very very important.

So I think, though this may be naive, that the first stage is just to be aware of this situation and to communicate these kinds of issues and to redouble our efforts. The good news is that a lot of these things we might need to do for diets and biofuels might be good for us. Eating less red meat might be good for a lot of us around the world, in terms of cardiovascular health or waistlines, etcetera. Producing more grass-fed beef, which, you know, most countries already do other than the US. Having more, maybe not vegetarian diets exclusively, but more vegetarian mixtures in our diets is probably good for our health and so on.

Hopefully we can reform what the western diet is already doing through a health lens but also maybe through the food security lens. And then, secondly, really see the developing countries and transitional economies leapfrog over the mistakes of our past and maybe settle on diets that are better for them and the world in the long run. However, it's an enormous challenge and one that won't be solved overnight.

Moderator *(Shaun Coffey)* Thank you very much ladies and gentlemen. We'll need to bring things to a conclusion there. If I might just reflect on a couple of things in terms of the conference. We've heard an enormous amount over the last day and a bit and particularly this morning. There's a couple of things that struck me as having not been commented upon yet, but I think they are significant outcomes in the last couple of days too. It's been really great in this

conference to see that we're finally recognising the role of women in agriculture and particularly in smallholder agriculture, and it's now becoming an accepted norm, as opposed to something that we've really not consciously recognised and acknowledged the way we have in this conference.

The second thing: a lot of the discussion this morning has been about the generational renewal that's needed in communities such as this. I think it's really nice, reflecting on having attended quite a number of these conferences, to see a lot more younger members of the community, the agricultural science community and the food community here today. And I guess there's one thing that's come out a lot from what we've talked about, and it is that when you look at all of the initiatives about, and all that we can do, there is a tremendous amount of optimism around and I think that's been particularly good.

Thank you.

Delegates and Agricultural Student Scholars 2012

Delegates to the 2012 conference are listed below, except for those who requested privacy from publication. Among the names are 17 young Australian agricultural scientists (asterisked) whose travel and attendance were sponsored by the Crawford Fund. This initiative supports the Fund's aim of increasing young Australian agricultural scientists' involvement in international agricultural development.

AGYARKO-MINTAH, Eunice	University of New England
AMAEFULA, Adanma	The University of Melbourne
ANDERSON-SMITH, Bronnie	Australian International Food Security Centre
ANDERSON AO, John	The Crawford Fund
ANDREW, Carolyn	
ANDREW AO, Neil	The Crawford Fund, South Australia
ANDREWS MP, Kevin	Federal Member for Menzies
ANGUS, John	CSIRO Plant Industry
APAN, Armando	University of Southern Queensland
ASANTE, Bright	University of New England
ATKINSON AO, Sallyanne	The Crawford Fund
AUSTIN, Nick	ACIAR
AYONDA, Dina Iga	The University of New South Wales
AZAM, Gausul	The University of Adelaide
BADGER, Murray	The Australian National University
BAI, Xuemei	The Australian National University, Fenner School
BARLOW, Snow	The University of Melbourne
BARSON, Michele	Dept of Agriculture, Fisheries & Forestry (DAFF)
BARTLETT, Tony	ACIAR
BAXTER, Peter	AusAID
BEDDINGTON CMG FRS, John	UK Government, Chief Scientific Adviser
BEKUMA, Amanuel Asrat	Murdoch University, Student
BELLOTTI, Bill	University of Western Sydney
BEOWULF, Thorsten	Student
BETT, Bosibori	QUT/CSIRO
BLIGHT AO FRSA, Denis	The Crawford Fund
BLIGHT, Sharon	
BRENNAN, Tony	British High Commission
BRETTELL, Richard	
BRUCE, Caroline	CSIRO
BUCKLE, Ken	The University of New South Wales
BUNTON, Alexandra	Dept of Agriculture, Fisheries & Forestry (DAFF)
BURGESS, Jillian	Burgess International
BURGESS, Lester	Burgess International
BUSH, Russell	The University of Sydney
BYERLEE, Derek	
*CAMERON, Kaylia	University of Tasmania
CAMPBELL, Andrew	Charles Darwin University
CAMPBELL, Sebastian	The University of Sydney
CARBERRY, Peter	CSIRO
CHAPPLE, Katrina	The University of Queensland
CHELL, Rosanna	Gansu Agricultural University

CHIDEY-PHIRI, Grace	Curtin University
*CHRISTENSEN, Johanna	The University of Melbourne
CLEMENTS, Bob	
COFFEY, Shaun	Industrial Research Ltd, New Zealand
CONNELL, John	James Cook University
COUGHLAN, Kep	The Crawford Fund
COVENTRY, David	The University of Adelaide
CRASWELL, Alison	
CRASWELL, Eric	The Crawford Fund
CULLEN, Jim	CRC Plant Biosecurity
CUMMING, James	Canberra Institute of Technology
CUNNINGHAM, David	ABARES, Dept of Agriculture, Fisheries & Forestry
DALTON, John	Seeds of Life
DALY, Joanne	CSIRO
DAVIES, Campbell	CSIRO
DE ALMEIDA, Octavio	Ministry Agriculture & Fisheries
DELFORCE, Julie	Office of National Assessment
DENT, Kelly	Oxfam Australia
DI NATALE, Richard	Senator for Victoria, Australian Greens
DIXON, John	ACIAR
DOEPEL, David	Africa–Australia Research Forum
DONALDSON, Kirstin	World Vision Australia
*DOOLETTE, Casey	The University of Adelaide
DORNOM, Helen	Dairy Australia
DO ROSARIO FERREIRA, Adalfredo	Ministry Agriculture & Fisheries
DOWNARD, Christie	Dept of Agriculture, Fisheries & Forestry (DAFF)
DREW, Mark	Australian Khyber Pakhtunkhwa Ag. Dev. Org.
DUNCAN, Ron	The Australian National University
ECKER, Saan	ABARES, Dept of Agriculture, Fisheries & Forestry
EDGAR, Robert	Victorian Crawford Committee
EDMEADES, Chris	CABI, Australia, NZ & Japan
ENRIGHT, Terry	The Crawford Fund, WA Committee
EVANS, John	The Australian National University
EVANS, Lloyd	
FALVEY, Lindsay	Hassad Australia P/L
FALVEY-BEHR, Simone	
FAN, Shenggen	International Food Policy Research Institute
FARLEY, Jeremy	The Crawford Fund
FARRELL, Terence	AARES
FISCHER AM FTSE, Tony	The Crawford Fund
FITT, Gary	CSIRO, Biosecurity Flagship
FITZPATRICK, Lesley	Australian Rural Leadership Foundation
FOLEY, Jonathan	Institute on the Environment, University of Minnesota
FOTIA, Marijke	Austraining International
*FOWLER, Stephanie	Charles Sturt University
FUJITA LAGERQVIST, Yayoi	The University of Sydney
*GALE, David	Department of Primary Industries, NSW
GARNETT, David	
GARNETT PSM FTSE FAICD, Helen	The Crawford Fund
GARTMANN, Alexandra	Foundation for Rural and Regional Renewal
GIBBS, Diana	Murray-Darling Basin Authority
GLATZ, Phil	SARDI
GODDEN, David	The Crawford Fund, NSW Committee

GOH, Chooi Hua	The Australian National University
GOLDIE, Jenny	Sustainable Population Australia
*GOODE, Imogen	La Trobe University
GREADY, Jill	The Australian National University
GREGSON AM FTSE, Tony	The Crawford Fund
GRIFFIN MP, Alan	Federal Member for Bruce
GUINNESS, Anthony	Agricultural Management Services, Landmark Operations Ltd
GUNNING-TRANT, Caroline	Dept of Agriculture, Fisheries & Forestry (DAFF)
GUY, David	
GYLES, Mandy	ACIAR
HAFID, Hiswaty	The University of Sydney
HANKS, Jenny	ACIAR
HARCH, Bronwyn	CSIRO, Sustainable Agriculture Flagship
HARDMAN, Joy	ACIAR
HARTING, Graziella	National Economic & Development Authority
HARTLEY FTSE, Margaret	The Crawford Fund / ATSE
HARVEY, John	Grains Research & Development Corporation
HAYES FAIAST, Ted	The Crawford Fund
HAYES MP, Chris	Federal Member for Fowler
*HEALEY, Madaline	Agri-Science, Queensland
HEWITT, Joanna	ACIAR, Commission Chair
HICKEY, Georgina	ACIAR
HIGGINS, TJ	CSIRO
HING FAY, Eleanor	The Australian National University
HONG, Jun	China National Animal Husbandry Services
HUTTNER, Eric	ACIAR
INALL, Neil	The Crawford Fund, NSW Committee
INGRAM, Jim	United Nations World Food Programme
ISLAM, Md. Jakiul	Faculty of Fisheries, Sy Ihet Agricultural University
JEFUKA TURO, Chala	Curtin University
JEHNE, Claus	
JEHNE, Walter	Healthy Soils Australia
*JENKISON, Rebecca	Curtin University
JIAN, Wang	Tibet Poverty Alleviation Office
JOHNSON, Mary	RMIT University
JOHNSON, Nathan	Dept of Agriculture, Fisheries & Forestry (DAFF)
JONES, Jan	
KEERTHISINGHE, Gamini	ACIAR
KERIN AM FTSE, John	The Crawford Fund
*KERR, Clare	Department of Agriculture, Queensland
KHARIS, Ruth	The Australian National University, NCEPH
KILBY-LUHRS, Alexis	Canberra Institute of Technology
KOMUGISHA, Basiita Rose	James Cook University
KOVACEVIC, Svetozar	British High Commission
KOYZREVA-MORGAN, Tatiana	Canberra Institute of Technology
LANSLEY, David	World Vision Australia
LAW, Cathryn	GO Science, United Kingdom
LAWRENCE, Janet	The Crawford Fund, Queensland Committee
LEIGH, Roger	The University of Adelaide
LEITH, Peat	Tasmanian Institute of Agriculture
LEMERLE, Caroline	
LINEHAN, Verity	Dept of Agriculture, Fisheries & Forestry (DAFF)

*LIVINGSTON, Gavin	University of Tasmania
LLOYD AM, Bruce	The Crawford Fund, Victoria
LOKE, Wai-Hong	CABI, South-East and East Asia
LOPEZ, Patricia	Timothy G. Reeves and Associates P/L
LOVETT, Anwen	Rural Industries Research & Development Corp.
LOVETT, John	The Crawford Fund, ACT
LUKUYU, Margaret	University of New England
MACDONALD, Ian	Shadow Parliamentary Secretary for N. Territory
MACFADYEN, Sarina	CSIRO
MACHARIA, Isaac	University of New England
MACKINNON, Ian	The Crawford Fund
MAHESHWARI, Basant	University of Western Sydney
MARCAL DE ARAUJO, Januario	Ministry Agriculture & Fisheries, East Timor
MARINO MP, Nola	Federal Member for Forrest
McBRIDE, Rebecca	ACIAR
McCOMB, Arthur	Murdoch University
McCOMB AM FTSE, Jen	The Crawford Fund
McCORMACK MP, Michael	Federal Member for Riverina
McCOWN, Bob	CSIRO
McGARTY, Craig	Murdoch University
*McGOWAN, Ben	Victoria, Scholar
McGOWAN AO, Cathy	Australian Women in Agriculture
McKENZIE, Bridget	Senator for Victoria; Nationals
McKENZIE, Fiona	The University of Sydney
MEIBSUCH, Sarah	QAAFI
MENDHAM, Neville	The Crawford Fund
MENDHAM, Robyn	
MEWETT, Osman	CropLife Australia
MIDGLEY, Stephen	Salwood Asia Pacific Pty Ltd
MILLIGAN, Ann	ENRiT: Environment & Natural Resources in Text
MOORE, Joseph	Charles Sturt University
MORAN, Chris	Sustainable Minerals Institute
MORELL, Matthew	CSIRO
MUHINDIRA, Paul Visendi	The University of Queensland
MUIR, John	Ecofibre
MUMFORD, James	Adelaide University Agriculture Students Association
MUYLAERT, Paul	The University of Queensland, School of Geography
MWARE, Benard	QUT
NAIDU, Ravi	CRC CARE
NANYUNJA, Robinah K	Pilot International
NEALES, Sue	The Australian
NEILSON, Jeff	The University of Sydney
NELSON, Sam	Rural Industries Research & Development Corp.
NICHOLLS, Trevor	CAB International
NJACI, Isaac	QUT
*NOACK, Sarah	The University of Adelaide
NOBLE, Andrew	International Water Management Institute
NORWOOD, Catherine	Coretext Pty Ltd
O'REAGAIN, Joe	Fitzroy Basin Association
OAKESHOTT MP, Robert	Federal Member for Lyne
PADOCH, Christine	Centre for International Forestry Research (CIFOR)
PAGE, Girija	University of Western Sydney
PARSONS, David	University of Tasmania, Tas. Institute of Agriculture

PASSIOURA, John	CSIRO Plant Industry
PEACOCK, Tony	CRC Association
PENGELLY, Bruce	CSIRO
PERSLEY, Gabrielle	The Doyle Foundation
PRATLEY, James	Charles Sturt University
PRENTICE MP, Jane	Federal Member for Ryan
PRESTON, Aaron	Charles Sturt University
PRICE, Dean	The Australian National University
PRIOR, Julian	University of New England
PRITCHARD, Bill	The University of Sydney
PURBRICK, Steve	Austraining International
RADCLIFFE AM FTSE, John	The Crawford Fund
RAMSEY MP, Rowan	Federal Member for Grey
RANGEL, Gil	Ministry Agriculture & Fisheries
READE, Cathy	The Crawford Fund, Conference Director
REEVES, Timothy	Timothy G. Reeves and Associates P/L
REID AO, Margaret	The Crawford Fund
RIDLEY, John	C-Logic
RIDSDILL-SMITH, James	CSIRO
RIJSBERMAN, Frank	CGIAR Consortium
RITMAN, Kim	Dept of Agriculture, Fisheries & Forestry (DAFF)
ROBERTS, Stacy	International Food Policy Research Institute
RODRIGUEZ, Daniel	The University of Queensland
ROLA-RUBZEN, Fay	Curtin University
ROXBURGH, Caspar	La Trobe University
RULE, Joshua	Office of Senator Edwards
*RYAN, Kelly	Department of Agriculture and Food, WA
RYAN, Michael	Dept of Agriculture, Fisheries & Forestry (DAFF)
SAMUNDSETT, Colin	
SANGINGA, Charlotte	
SANGINGA, Nteranya	International Institute of Tropical Agriculture, Nigeria
SAR, Lily	PNG University of Technology
SAYERS, Keith	ALP International Affairs Policy Committee
SCHNEEBELI, Kathy	CSIRO Plant Industry
SCOTT-ORR PSM, Helen	The Crawford Fund, NSW Committee
SHANAHAN, Olivia	ACIAR
SHEARER, David	ACIAR
*SHONK, Felicity	The University of Sydney
SIEWERT, Rachel	Senator for Western Australia, Australian Greens
SINN, Michelle	Dept of Agriculture, Fisheries & Forestry (DAFF)
SKERRITT, John	International Water Management Institute
SMIDER, Benjamin	The University of Sydney
SMITH, Andrew	The University of Adelaide and AVRDC
SMITH, Cynthia	
SMITH, Jack	
SMITH, Sally	The University of Adelaide
SMYTH MP, Laura	Federal Member for La Trobe
SODERBAUM, John	ACIL Tasman
SOEM, Thomas	The University of Sydney
STANDEN, Bruce	The Crawford Fund
STAPPER, Maarten	BioLogic AgFood
STIRZAKER, Richard	CSIRO Land & Water
STONE MP, Sharman	Federal Member for Murray

STOUTJESDIJK, Peter	ABARES
TAMANG, Sujata	The University of New South Wales
*TARBATH, Michael	University of Tasmania
TAVERNER, Mike	
TEMPLETON, Deborah	ACIAR
THORNE, John	The Australian National University
*TILLACK, Alex	Southern Cross University
TRIBE, Elizabeth	
TRIBE, Jane	
VAN OOSTENDE, Marchien	The Crawford Fund
VELARDE, Sandra	The Australian National University
VERRIER, June	
VICOL, Mark	The University of Sydney
VON CAEMMERER, Susanne	The Australian National University
WALKER, Daniel	CSIRO Ecosystem Sciences
WALLACE, Mark	The Australian National University
WALSH, Tom	CSIRO
WANG, Guanglin	ACIAR
WANG, Zongli	China Ministry of Agriculture
WATSON, Harold	Canberra Institute of Technology
*WATSON, Laura	CSIRO Plant Industry
WEDGWOOD, Sara	CSIRO
WEGENER, Malcolm	AARES
WICKES, Roger	The Crawford Fund, South Australia
WILLIAMS FTSE, John	John Williams Scientific Services Pty Ltd
WILSON, Michelle	British High Commission
WINDSOR, Peter	The University of Sydney
WINTER, Simon	Rural Industries Research & Development Corp.
WONDER, Bernard	AIFSC
WYNN, Peter	Charles Sturt University, Animal & Veterinary Science
XIANGYANG, Hou	Grassland Research Institute
ZAPPIA MP, Tony	Member for Makin, South Australia
ZHANG, Yingjun	China Forage Research System
ZHIBIAO, Nan	Lanzhou University

Media coverage 2012

TV:

ABC TV News Breakfast: Derek Byerlee – Monday, 8.40am

ABC TV Weekend Breakfast: Denis Blight – Sunday, 13.10 10.30am

PRINT/ONLINE:

The Australian: Rijsberman/Beddington http://www.theaustralian.com.au/news/nation/farmers-face-test-as-food-demand-soars/story-e6frg6nf-1226492392251

The Australian: Byerlee/Foley (11.10) http://www.theaustralian.com.au/news/world/world-land-grab-well-advanced-as-supply-runs-short/story-e6frg6so-1226493210496

Online Opinion: Rijsberman op ed http://www.onlineopinion.com.au/view.asp?article=14202

Weekly Times – Byerlee http://www.weeklytimesnow.com.au/article/2012/10/08/544429_national-news.html

Minister's Blog http://bobcarrblog.wordpress.com/ and Press Release covered in:

Food World News: Carr http://www.foodworldnews.com/articles/2740/20121010/australiafoodinsecureafricafoodpriceunrest.htm

Ninemsn: Carr http://news.ninemsn.com.au/national/8545036/aust-to-lead-on-global-food-security-carr

Bernama Malaysia: Carr http://www.bernama.com/bernama/v6/newsworld.php?id=700519

4-traders http://www.4-traders.com/news/AusAID-Australian-Agency-for-International-Devel-Australia-boosts-food-security-commitment-to-Af--15316601/

West Australian http://au.news.yahoo.com/thewest/a/-/national/15068955/aust-to-lead-on-global-food-security-carr/

Herald Sun http://www.heraldsun.com.au/news/breaking-news/aust-to-lead-on-global-food-security-carr/story-e6frf7kf-1226491895550

Perth Now http://www.perthnow.com.au/news/breaking-news/aust-to-lead-on-global-food-security-carr/story-e6frg13c-1226491895550

The West http://au.news.yahoo.com/thewest/a/-/national/15068955/aust-to-lead-on-global-food-security-carr/

The Australian http://www.theaustralian.com.au/news/breaking-news/aust-to-lead-on-global-food-security-carr/story-fn3dxiwe-1226491895550

News.Com http://www.news.com.au/breaking-news/national/aust-to-lead-on-global-food-security-carr/story-e6frfku9-1226491895550

Bernama http://www.bernama.com/bernama/v6/newsworld.php?id=700519

Weekly Times http://www.weeklytimesnow.com.au/article/2012/10/09/544831_national-news.html

Yahoo http://au.news.yahoo.com/thewest/a/-/national/15068955/aust-to-lead-on-global-food-security-carr/

Canberra Times: Byerlee "Foreign Buyers not a threat" http://www.canberratimes.com.au/national/foreign-buyers-not-a-threat-20121009-27bqy.html

The Melbourne Age: Byerlee "Farmland Sales nothing to fear" http://www.theage.com.au/opinion/political-news/farmland-sales-nothing-to-fear-20121009-27bap.html

I4U News – Byerlee http://www.i4u.com/2012/10/australia/foreign-land-grab-fears

TV Balla – Byerlee http://www.tvballa.com/2012/10/china/about-raid-fears-unfounded-land-chinas

Rijsberman: APN Newspapers "Science Key to Global Food Future":
http://www.caboolturenews.com.au/news/science-key-global-food-future/1576072/
http://www.mydailynews.com.au/news/science-key-global-food-future/1576072/
http://www.dailyexaminer.com.au/news/science-key-bal-food-future/1576072/
http://www.coolum-news.com.au/news/science-key-global-food-future/1576072/
http://www.whitsundaytimes.com.au/news/science-key-global-food-future/1576072/
http://www.byronnews.com.au/news/science-key-global-food-future/1576072/
http://www.noosanews.com.au/news/science-key-global-food-future/1576072/
http://www.echonews.com.au/news/science-key-global-food-future/1576072/
http://www.gattonstar.com.au/news/science-key-global-food-future/1576072/
http://www.qt.com.au/news/science-key-global-food-future/1576072/
http://www.centraltelegraph.com.au/news/science-key-global-food-future/1576072/
http://www.dailymercury.com.au/news/science-key-global-food-future/1576072/
http://www.thesatellite.com.au/news/science-key-global-food-future/1576072/
http://www.news-mail.com.au/news/science-key-global-food-future/1576072/
http://www.sunshinecoastdaily.com.au/news/science-key-global-food-future/1576072/
http://www.themorningbulletin.com.au/news/science-key-global-food-future/1576072/
http://www.gladstoneobserver.com.au/news/science-key-global-food-future/1576072/
http://www.gympietimes.com.au/news/science-key-global-food-future/1576072/
http://www.coffscoastadvocate.com.au/news/science-key-global-food-future/1576072/
http://www.frasercoastchronicle.com.au/news/science-key-global-food-future/1576072/
http://www.northernstar.com.au/news/science-key-global-food-future/1576072/
http://www.ballinaadvocate.com.au/news/science-key-global-food-future/1576072/
http://www.thechronicle.com.au/news/science-key-global-food-future/1576072/
http://www.warwickdailynews.com.au/news/science-key-global-food-future/1576072/
Byerlee: APN Newspapers: "Foreign Land Grab Fears"
http://www.thereporter.com.au/news/foreign-land-grab-fears/1573840/
http://www.gladstoneobserver.com.au/news/foreign-land-grab-fears/1573840/
http://www.dailymercury.com.au/news/foreign-land-grab-fears/1573840/
http://www.ballinaadvocate.com.au/news/foreign-land-grab-fears/1573840/
http://www.gympietimes.com.au/news/foreign-land-grab-fears/1573840/
http://www.frasercoastchronicle.com.au/news/foreign-land-grab-fears/1573840/
http://www.frasercoastchronicle.com.au/news/foreign-land-grab-fears/1573840/
http://www.thesatellite.com.au/news/foreign-land-grab-fears/1573840/
http://www.themorningbulletin.com.au/news/foreign-land-grab-fears/1573840/
http://www.thechronicle.com.au/news/foreign-land-grab-fears/1573840/
http://www.centraltelegraph.com.au/news/foreign-land-grab-fears/1573840/
http://www.coffscoastadvocate.com.au/news/foreign-land-grab-fears/1573840/
http://www.mydailynews.com.au/news/foreign-land-grab-fears/1573840/
http://www.news-mail.com.au/news/foreign-land-grab-fears/1573840/
http://www.qt.com.au/news/foreign-land-grab-fears/1573840/

http://www.gattonstar.com.au/news/foreign-land-grab-fears/1573840/

http://www.whitsundaytimes.com.au/news/foreign-land-grab-fears/1573840/

http://www.thesatellite.com.au/news/foreign-land-grab-fears/1573840/

http://www.themorningbulletin.com.au/news/foreign-land-grab-fears/1573840/

http://www.thechronicle.com.au/news/foreign-land-grab-fears/1573840/

http://www.coffscoastadvocate.com.au/news/foreign-land-grab-fears/1573840/

http://www.mydailynews.com.au/news/foreign-land-grab-fears/1573840/

http://www.qt.com.au/news/foreign-land-grab-fears/1573840/

http://www.gattonstar.com.au/news/foreign-land-grab-fears/1573840/

http://www.caboolturenews.com.au/news/foreign-land-grab-fears/1573840/

http://www.sunshinecoastdaily.com.au/news/foreign-land-grab-fears/1573840/

CGIAR Blog Noble: http://wle.cgiar.org/blogs/2012/10/10/water-and-land-degradation-a-slumbering-giant/

RADIO:

RN Bush Telegraph (18mins): Nicholls/Rijsberman http://www.abc.net.au/rural/telegraph/content/2012/s3606039.htm

RA Connect Asia: Fan http://www.radioaustralia.net.au/asia/radio/program/connect-asia/global-food-security-a-serious-concern-says-researcher/1027052

RA Connect Asia: Blight/Persley

ABC Chinese: Fan

RA Connect Asia: Padoch http://www.radioaustralia.net.au/asia/radio/program/connect-asia/seeing-the-forests-for-the-trees/1027786

RA Pacific (live):– Nicholls, Foley

ABC News Radio (live): Byerlee

ABC Rural: Rijsberman/Nicholls http://www.abc.net.au/rural/tas/content/2012/10/s3607728.htm

National Commercial Rural News – Nicholls

National Commercial Rural News – Rijsberman

National Community and Indigenous Radio – The Wire: Blight http://www.thewire.org.au/storyDetail.aspx?ID=9701

ABC Canberra Tony Peacock – Nicholls

ABC National Rural News: Noble http://www.abc.net.au/rural/news/content/201210/s3608502.htm

ABC Country Hour – Adelaide http://www.abc.net.au/rural/sa/content/2012/10/s3608681.htm

THE CRAWFORD FUND
For a Food Secure World

For further information, to support us or to be kept informed of the Crawford Fund's work, contact:

PO Box 4477 Kingston ACT 2604
+61 2 6188 4370
www.crawfordfund.org
ABN: 86 141 714 490

An initiative of the Australian Academy of Technological Sciences and Engineering