Crawford Fund FOR A FOOD SECURE WORLD

WEATHERING THE 'PERFECT STORM'

Addressing the Agriculture, Energy, Water, Climate Change Nexus

The Crawford Fund
2019 ANNUAL CONFERENCE
Parliament House, Canberra, Australia

12–13 August 2019

Editor Ann Milligan

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The Crawford Fund

The Australian Academy of Technology 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 Government's aid program, particularly with the Australian Centre for International Agricultural Research (ACIAR), the CGIAR Consortium, and other international research centres. The Crawford 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.

We also support and encourage the next generation in their study and careers in international agricultural research, through our international agricultural student awards and our Crawford Fund Conference scholarships and related activities, and by providing volunteering opportunities in our mentoring program.

The annual Conference is a key part of the Fund's public awareness campaign to increase understanding of key food and nutrition security issues and the importance and potential of international agricultural research.

The Crawford Fund
Building 7, Unit 7, 1 Dairy Road,
Fyshwick ACT 2609, Australia

Phone: +61 (0)2 6280 8611

Email: crawford@crawfordfund.org

Web: http://www.crawfordfund.org

Twitter: @CrawfordFund

YouTube: https://www.youtube.com/user/Crawford Fund

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We wish to thank the following institutions and individuals who have supported or made donations helping support 21 conference scholars this year. In addition, our State and Territory Committees have supported 30 other conference scholars.

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The University of Queensland School of Agriculture and Food Sciences
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Foreword

For 2019, the Crawford Fund's annual conference tackles a very important topic: Weathering the 'perfect storm'; addressing the agriculture, energy, water, climate change nexus.

That this topic is recognisably forward-looking has been confirmed by there being so many young people in this year's conference audience. The future of the world, including our country and our standard of living and our security, will in many ways very shortly rest in the hands of today's young people.

Our conference focus on the agriculture, climate change, water, energy nexus highlights the major challenges this nexus poses to the developed and developing worlds alike.

The 'perfect storm' in our conference title is the term Sir John Beddington coined in 2009, when he was the UK Chief Scientist. He used that term to describe his prediction that, by 2030, food shortages, scarce water and insufficient energy resources would threaten to unleash public unrest, cross-border conflict and mass migration, as people fled from the worst affected regions. Indeed, when Sir John gave our Sir John Crawford Memorial Address in 2012, he touched on many of the topics of this year's conference.

Is the storm still on track to happen? Or can scientific, engineering and agricultural innovation, and what is happening in farmers' fields, lessen or delay its impact? That is what we aim to explore in this conference. Can we achieve the positive future set out for us by Professor Ross Garnaut AC in this year's Sir John Crawford Memorial Address?

'NextGen' – the way ahead

NextGen is the term we at the Crawford Fund have adopted for our emphasis on supporting young scholars to enter international agricultural practice and research. It is with great pleasure that I can tell you there are 51 conference scholars this year, from all around Australia. Further, there are another 60 or so young people in this year's audience – and I and other members of the Fund's board look forward to meeting and encouraging them.

Yesterday I was very pleased to be able to announce at our scholars' activities afternoon a further boost to our NextGen work, with support from ACIAR thanks to Andrew Campbell its CEO. This will further improve awareness of the varied, meaningful and beneficial outcomes for Australian students, for Australian agriculture and for developing countries where our NextGen work is, and will be, engaged.

This year we are pleased to again have the support of the young researchers of RAID (Researchers in Agriculture for International Development). Two of its members, Madaline Healey and Rebecca Cotton, are our conference Keynote Listeners. They are noting the key messages from the talks, and also the major 'take-outs' that they hear from others in the audience. It is important

for the world that the points arising in this year's conference get wide dissemination, and stimulate policies and actions, and that those in turn gain momentum. Action and momentum are important for the world preparing to weather this 'perfect storm'.

Acknowledgements

I would like to acknowledge the supportive message (see page 1) sent this year by the Minister for Foreign Affairs, Marise Payne, who is not able to be with us.

Particularly important are the many conference and scholar supporters (listed above on pages v–vi). It wouldn't be possible to hold this event without their support: indeed, some of these groups and individuals have supported this annual conference now for many, many years. Thank you all.

The Hon. John Anderson AO
Chair, The Crawford Fund

Conference scholars, and members of the Board, the state and territory committees, and the staff of the Crawford Fund, August 2019.

Message from Senator the Hon. Marise Payne, Minister for Foreign Affairs and Minister for Women

The Crawford Fund Conference is an important event on the international agricultural development and food security calendar. Water, food and energy are critical to all of our daily lives.

I am sorry that I am not able to attend the conference this year and warmly welcome the opportunity to contribute to this event.

The conference features a presentation from Biofilta who, with the support of DFAT, have developed easily portable, raised garden beds. I have had the pleasure of seeing this technology first hand in Tuvalu. Innovations like this can change how food is produced in some of the challenging environments of Pacific Island countries, which are particularly impacted by climate change.

I would like to acknowledge the important role ACIAR plays as a trusted science partner across our region. ACIAR uses Australian know-how to work with partner countries to empower smallholder farmers, scientists and policymakers. Especially important for me is that many ACIAR projects are improving women's access to resources and giving them a voice in decision making. We know empowering women is key in reducing poverty at the family and community levels.

Water availability has always been at the heart of agricultural production. Australia is a leader in the management of water resources. We have valuable experience from decades of water reform that we share with our international partners. For example, our Australian Water Partnership has some 200 partners representing Australian expertise across government, private, university and civil society sectors. They provide considerable technical assistance and advice to partner governments.

With such a high-calibre collection of international and Australian thinkers and practitioners I have no doubt that this year's Crawford Conference will be an outstanding success. I wish you all the best for the Conference and thank the Crawford Fund for continuing to lead on these important issues.

This message from the Minister was read out by the Hon. John Anderson AO during his welcome address at the start of the conference.

Sir John Crawford Memorial Address 2019

Australia can be a superpower in a low-carbon world economy

Professor Ross Garnaut AC
The University of Melbourne

Abstract

To John Crawford, the role of economics was to illuminate real world conditions and improve policy options. At a time of historic change in climate and Australia's international environment, we need Crawford's approach to economics as never before. Growth in global population and incomes, and climate change, are putting pressure on land and water resources. Transformation of land use and food consumption are important dimensions of the response to climate change. Australian research skills in agriculture, biology, botany, engineering and economics can secure the Australian transformation and extend it internationally. The challenges of climate change are especially acute and the opportunities exceptionally large in Australia. The drying and warming of southern Australia is undermining established agricultural and pastoral activities. But rural and provincial Australia have global comparative advantage of considerable value in activities the value of which will be greatly increased in the zero-carbon emissions world that is necessary to limit damage from climate change: renewable energy resources; opportunities for biomass production as a zero-emissions source of inputs into industrial activities; and the opportunity for sequestration of carbon in Australian soils, pastures, woodlands and savannahs, and forests.

My wife Jayne and I have spent the last two weeks travelling through the Murray–Darling Basin. Down the Murray from Swan Hill to Mildura and Wentworth. A couple of days at Lake Mungo, where the ice age overflow from the Lachlan once filled lakes and supported communities that left us with what may be the oldest record on Earth of complex human mind and spirit. Then up the Darling to the Menindee Lakes; cutting across through Broken Hill to Wilcannia, once the bustling third port in Australia; then back south, across the Lachlan at Hillston, and the Murrumbidgee near Griffith, finally reaching the Murray again. Beautiful Australian country. Rich with the human heritage of 50,000 and 200 years.

It is also a personal heritage for many Australians. John Crawford spent his early years at Grenfell, in the catchment of the Lachlan; and most of his professional life here in Canberra in the catchment of the Murrumbidgee.

Jayne's father, Tom Potter, lived in Wentworth and the lower Darling until he and many others in the bush rode to Melbourne on the news of war in 1914. That ride led to a beach in Turkey as the sun rose above the coastal hills on

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Professor Garnaut's address quotes extensively from his latest book, *Superpower. Australia's low-carbon opportunity*, which was published in November 2019, three months after the 2019 Crawford Fund conference.

25 April 1915. When we visited Wentworth nearly a decade ago, a board in the RSL Club remembered Tom and his brother. The building that housed the Club and its memorabilia is now empty beside the Darling.

What value do we place on Australian heritage? The question kept coming back as we travelled up the Darling. For about 30 kilometres the bottom of the riverbed is wet from the flow-back from the Murray. From there, the sand between the rows of grand old river gums is dry, except for scattered stagnant pools. By one pool, the skeletal head of a Murray Cod gaped wide enough to swallow whole the biggest carp. The dried flesh on the cod's back had been depleted by wild pig bites when it was still fresh – by pigs that were able to wade into the shallow pond and drag out the helpless survivor of decades.

Around a big fire on the riverbank one night, we were told of a plan to ride a motor bike along the dry Darling bed from above Wentworth to the dry Menindee Lakes. It was the first time anyone could have made the ride.

We were travelling through an Australian tragedy. A tragic consequence of denial of knowledge and of its role in public policy. A denial, I had been thinking, of the life's work of a man from the Lachlan. And then, last Wednesday, between Menindee and Broken Hill, I received a call asking if I would address this dinner.

Policy used to be based on research and understanding

I recalled a conversation with Sir John as we travelled around the south-east Asian capitals in 1979 at the request of Prime Minister Malcolm Fraser. We were recruiting participants in the Pacific Community Seminar, precursor of the Pacific Economic Cooperation Council and then APEC.[1] I asked about his time as Director of Research in Minister Dedman's and Secretary Coombs's Department of Post War Reconstruction, when there was early discussion of the Snowy Mountains Scheme. He told me that an early concern with Snowy was whether there would be markets for increased production from irrigation on the Murrumbidgee and the Murray, so he set people onto research into the global markets for dried fruits and wine.

John Crawford – Jack to most of his contemporary friends, and Sir John or Professor Crawford to young members of staff – was an important part of a remarkably productive period in Australian government, scholarship and public life, stretching – with ebbs and flows – from the war years through to a decade or so beyond the end of Sir John's life.

Crawford's special contribution over four decades was to insist that sound policy began with knowledge; that sound knowledge emerged from research; and that expanding an understanding of policy choices through public education was an essential part of the policy-making process.

Here at the Crawford Fund we remember especially Crawford's role in the establishment of the International Food Policy Research Institute, the system of international agricultural research centres, the Indian Green Revolution; the

[1] APEC, the Asia–Pacific Economic Cooperation, is a forum of over 20 economies.

Australian Centre for International Agricultural Research; and, for those with longer memories, the Australian Bureau of Agricultural Economics. His policy and institutional legacy also includes more productive cooperation amongst peoples and countries of different and sometimes divergent cultural and political backgrounds. Examples include Australian contributions to the early and temporarily successful policy-making in the new Independent State of Papua New Guinea; economic relations with Japan after a horrific war; economic and educational exchange with China after the Cold War; and the most expansive era of trade and other economic relations across an emerging Asia–Pacific community.

Today, public policy based on the marshalling of knowledge through research and analysis, followed by a nurturing of public understanding of the issues, seems a distant dream. That it is dream and not contemporary reality is the essential problem behind the tragedies of the Murray–Darling Basin and of policy on climate change and the energy transition. At an international level, it is an essential problem in global trade and development.

Tonight, my talk is mainly about land and agriculture and regional development in Australia as we respond to the challenge of human-induced climate change. As always, on every development issue, but more on climate change than others, an Australian development question has an international context.

The 2008 *Garnaut Climate Change Review* drew attention to the historic lift in world food prices in the first decade of the new century. This broke a half century of declining relative prices, as increased yields, partly resulting from international public sector agricultural research, outran rising global population and living standards. An acceleration of the lift in living standards in the populous countries of Asia would make this an expanding opportunity over a long period for Australian farmers and therefore for Australians — unless climate change at home damaged Australian supply capacity.

Unfortunately, Australian farm capacity would be reduced by any failure of global climate mitigation. The atmospheric physics was telling us that the southerly movement of climate patterns, and therefore the drying as well as warming of the southern Australian latitudes that had been the home of most Australian agricultural value, would be a feature of climate change. Irrigation output in the Murray–Darling Basin was likely to decline by 90% in the absence of effective global mitigation.

New knowledge has reduced uncertainty without much changing the mean expectations about global warming.

We can now see in empirical observations the effects once anticipated from the atmospheric physics. Average temperatures across Australia so far this century are over a degree higher than in the first half of the 20th century.

We now see that streamflows into Perth dams, like for like, have contracted from an average of 336 GL per annum in the first three-quarters of last century, to 59 GL p.a. over the decade after I presented my first Report to State Premiers and the Prime Minister. That has made that city of over 2 million people mainly reliant on desalination and depleting groundwater. The south-west agricultural areas are facing great challenges.

We have reliable records of inflows into the Murray since 1892. After taking out the Snowy and inter-valley transfers, and the highly variable and currently zero flows from the Darling, average inflows averaged a bit over 9 teralitres (TL) per annum for the first 40 years of the record. The next 40 years, the annual average was over 9.5 TL. In the four decades commencing 1972, as a warming trend emerged more strongly and clearly, the annual average was 9 TL. In the 7 years since then, the average was a bit over 7 TL – a quarter below the first century of observation.

The controversial Murray–Darling Basin Plan does not take account of declining inflows as a result of climate change. Even this modest Plan, built on hope in contradiction of scientific analysis, has proven to be too demanding to implement as designed.

Hotter in Australia

The most ambitious of the Paris objectives would see average global temperatures increase by about 1.75°C from pre-industrial averages over the whole of the Earth's surface. The atmospheric physics tells us that temperatures over land will increase by more than that – for Australia, by more than twice the increase we have already experienced. To have good prospects of holding the temperature increase down to this level – something like 2.5°C increase on land – would require zero net global emissions by the middle of the century. That is not impossible. But it would require many things to go well.

The international community has accepted that some developing countries will take longer than developed countries to achieve complete decarbonisation. So Australia's fair share will be zero net emissions before mid-century – earlier still if we start serious reduction slowly, as we have done.

Even 1.75°C on average over the Earth's surface – the most optimistic outcome from the global mitigation effort – would present a massive adaptation challenge for Australia. It is a challenge for what we must do in Australia which, of the developed countries, is the most vulnerable to damage from climate change. It is also a challenge for managing the consequences of climate change in highly vulnerable countries in south Asia, south-east Asia and the south-west Pacific. Many of our neighbours will face extreme problems of adjustment, and their problems will certainly and quickly become shared problems.

We cannot be certain of success in holding global temperature increases to 1.75°C. The whole world, with Australia contributing its full share, would have to move quickly to zero net emissions to hold the adaptation challenge to 1.75°C. Continuation of current tendencies in Australia, if reflected elsewhere, would see us adjusting to temperature increases two or three times that level. One has to hope that proximity to the consequences of weakly mitigated climate change will lead to more realistic policies.

I have spent my life on the optimistic end of the Australian spectrum in discussion of many policy and development issues. That optimism has mostly been vindicated by the unfolding of history. On the challenge of adapting to weakly mitigated climate change, I am not optimistic. I fear that the challenge would be beyond the capacity of contemporary Australian society and polity. I fear that things would fall apart.

The bad news is that the passing of time, the results of new research and the accumulation of evidence are all broadly confirming the conclusions towards which the atmospheric physics led us a decade ago.

The good news is that the economic challenge of mitigation to reduce the damage from climate change now looks much less costly and daunting – for the world and especially for Australia, and above all for rural and provincial Australia. The good news is very good.

Improved economics now

The improvement in the economics has two main sources. One is an extraordinary fall in the cost of solar and wind energy and of storage to balance its intermittency. The second is realisation that there is opportunity for capturing and sequestering, at relatively low cost, immense quantities of atmospheric carbon in soils, pastures, woodlands and forests.

My 2008 Review for the Prime Minister, six Premiers and two Chief Ministers presented the results of comprehensive modelling of the costs and benefits of Australia participating in a strong global mitigation effort. It suggested that there would be some noticeable sacrifice of Australian current income until early in the second half of this century, but that average incomes would have regained lost ground by around the end of the century. The income benefits of strong mitigation were strongly positive beyond the 21st century. Effects on values beyond current incomes powerfully favoured strong mitigation.

Developments in the cost of renewable energy, energy-intensive transport and industrial processes, and carbon sequestration through changes in land

use would turn those calculations around if repeated today. Rapid shift to renewable energy within an appropriate policy and regulatory framework today would enhance Australian incomes. This would support Australian comparative advantage in energy-intensive manufacturing, including many processes that add value to mineral and agricultural products. Systemic incentives equivalent to the true cost of carbon emissions would lead to carbon sequestration via land use change becoming a major rural industry. I said in the 2011 Climate Change Review that the opportunity to sell farm carbon credits into the proposed emissions trading scheme would create a new rural industry as large as wool.

The 2008 modelling suggested that it would be cheaper for Australia to import large quantities of carbon credits from abroad rather than to achieve its targets entirely from reducing emissions at home. The Australian emissions trading scheme was due to be integrated into the European scheme from 1 July 2014. If those arrangements were in place today, with current understanding of renewable energy costs and opportunities for land-based sequestration in Australia, we could now expect Australia to be a major exporter of carbon credits.

This means that Australia could receive insurance against severe climate change impacts and at the same time enhance its own economic development by moving strongly and early towards decarbonisation of its economy. Both the climate change and economic benefits would accrue disproportionately to rural and provincial Australia.

More detail

Let me say a bit more about the two big changes affecting the cost of reducing emissions – the fall in the cost of zero-emissions energy; and the realisation of expanded opportunity in land-based sequestration of carbon.

First, **renewable energy**. The cost of capital goods for generating zero-emissions energy has fallen much more rapidly than had been anticipated in my 2008 Report, and there is no sign yet of deceleration of the decline. Interest and other costs of financial capital – the supply price of investment – represent the main cost of renewable energy and storage. This is unlike thermal energy, where recurrent costs of fuel are much more important. The supply price of investment has fallen dramatically over the past decade – with negative real yields on low risk bonds in all developed countries. The fall in the supply price of investment is disproportionately powerful in reducing the costs of zero-emissions energy. These two factors reinforcing each other – lower costs of capital costs for renewable energy and a lower supply price of investment – have caused the cost of renewable energy from wind and solar generation in favourable locations plus storage to be lower than the recurrent cost of thermal generation. They are lower than the total cost of thermal generation in many countries.

The fall in the cost of zero-emissions electricity also lowers the cost of decarbonisation of transport and industrial processes. There have also been large cost-reducing improvements in zero-emissions technologies to replace fossil coal, gas and oil in transport and industry.

The **potential for carbon sequestration** in soils, pastures, woodlands and forests figured prominently in my 2008 and 2011 Reviews. This led to the establishment of the Carbon Farming Initiative, later folded into the Emissions Reduction Fund. Australian research has surrendered the leading position it occupied on land-based sequestration at that time, but the international effort has been expanded. Recent reports from the US Academy of Science, the European Academies, and the August 2019 IPCC report[2] all point to a substantial proportion – a third or more – of required reductions in emissions to come from changes in land use at relatively low cost. CSIRO, the University of Melbourne and some other Australian research institutions have continued the effort, and the continued interest of former Governor-General Michael Jeffery has raised the possibility of substantial government support for this effort. It is a worthy and appropriate subject of major effort by ACIAR and some Institutes of the CGIAR.

Many opportunities for carbon sequestration through changes in land use involve high initial capital and relatively low subsequent recurrent expenditure. They are therefore also beneficiaries of the decline in the supply price of investment.

There is also good fortune for the global mitigation effort in changes over the past decade in the framework of global cooperation on climate change mitigations. These are reflected in the outcome of the Paris meeting of the UNFCCC[3] in late 2015, which defined a path to realisation of strong outcomes. The new approach, which I called 'concerted unilateral mitigation', was supported initially by all members of the UN except Nicaragua and Syria, and eventually by those two countries as well. Within this framework, all major countries were committed to major change in the trajectory of their emissions. Most, including the US and China, have made early progress on implementing their commitments.

Australia so far has been a drag on the international effort. Its initial target was 26–28% reduction in emissions on 2005 levels by 2030. Australian emissions have been rising since 2014, raising questions about achievement even of this unambitious target. However, the initial targets at Paris were subordinate to the overarching goal of holding temperature increases as far as possible below 2°C and as close as possible to 1.5°C, with peer assessment leading to progressive tightening of the targets over time.

What Australia does is influential. What the US and China do is much more influential. Regrettably, both China and the US, having made large contributions in the period up to and in the year after Paris, have since then been contributing less positively. The decisive change was the election of Donald Trump as President of the United States, with commitments to withdraw the US from the Paris Agreement, to reverse the trend towards declining coal use in the US, and more generally to retreat from action on climate change. This has weakened pressure on other states including Australia to raise their initial Paris targets.

[2] Intergovernmental Panel on Climate Change, August 2019, *Climate change and land.*
[3] United Nations Framework Convention on Climate Change

It has not immediately increased emissions in the US, where market pressures and private sector and state and city government activity continue to keep emissions on a downward path. However, an extended period in office of Trump or others of similar mind would eventually throw US emissions back onto a rising trajectory.

China's emissions had been the major source of increases in global emissions through the first decade of this century. Changes in the overall model of economic growth, as well as energy and industrial and climate change policy after 2012, fundamentally changed the trajectory of emissions reduction. There was no increase in emissions from 2013 to 2016. Policy change in the US did not prompt climate policy change in China. However, the Trump trade war that began in 2017 introduced uncertainty into Chinese policy-making, and reduced export, investment and output growth. China's response was fiscal and monetary expansion to offset negative international influences on growth. This reinforced the old emissions-intensive pattern of growth. The immediate effect has been the reassertion of the old model of economic growth based on investment in infrastructure and heavy industry with its high emissions intensity.

So the chances of reaching ambitious outcomes for global emissions have declined over the past two years. Australia's social and political capacity to manage major adaptive adjustment may be tested.

Transforming land use and agriculture in Australia

The 2008 (Chapter 22) and 2011 (Chapter 10) Reviews drew attention to the exceptional contribution to global as well as Australian mitigation that could be made by changing Australian land use.

Australia's comparative strengths have two sources.

The first is our exceptionally large endowments of woodlands, forests and other land relative to population. This has given Australia its historical comparative advantage in land-based products.

The second is our exceptional expertise in the land-based industries – from agricultural and forestry science, through agricultural and resource economics to public and private knowledge and institutional arrangements supporting commercial success.

I noted in 2008 that innovation in rural production and in regulatory arrangements was going to be necessary for Australia and the world to take full advantage of opportunities for mitigation through changes in land use. Rules for measuring and accounting for land use emissions were immature, and had to be developed on sound principles to make the most of global opportunities, and to recognise Australian contributions. Other developed countries which had shaped the rules did not share Australia's opportunity, or interest. Australian expertise could help to develop environmentally and economically efficient international rules. Our knowledge on land use transformation could be of particular assistance to Australia's neighbours in south-east Asia and the south Pacific.

The special Australian place in the absorption of carbon in the landscape was the subject of remarkable commentary eight decades ago by the first Distinguished Fellow of the Australian Economics Society, Colin Clark. In his 1940 book, *Conditions of Economic Progress*, Clark helped to found development economics and the use of national accounts for production and income. Clark sought to allay concerns that the dependence of modern economic development on fossil energy, and the finite nature of coal and oil resources, would bring economic growth to an end. He noted that we can calculate the likely amount of undiscovered fossil fuels from the carbon that was once in the atmosphere. He said:

> However, we must not set out to burn them up too fast, even if we do find them, at any rate not faster than the rate at which the carbon dioxide can be converted by photosynthesis...

But he reassured us that keeping the use of fossil fuels within the limits of what can be absorbed by photosynthesis need not be the end of economic growth. There is an abundance of solar energy falling on the Earth, if we know how to tap it. The best method at present, he said, is the proven process of photosynthesis in trees, and he calculated that the eucalypt is the most productive agent for conversion of solar energy into biomass at present. Algae had the potential to do better. The silicon battery and other recent discoveries, he said, may do better still some day (Clark, 1957 pp. 488–489).

So the importance of the Australian eucalypt to sustaining economic growth without excessive carbonisation of the atmosphere was recognised 80 years ago, at the beginning of development economics.

In 2008, I brought into the mainstream discussion some early work by the CSIRO and state departments of agriculture on the immense mitigation potential of changes in land use. The nurturing of vegetation on the dry degraded mulga country where rainfall was spasmodic in western Queensland and the rangelands of New South Wales could be transformative. Innovative uses of the properties of Australian eucalypts included farming of the mallee on the arid boundaries of crop cultivation for subterranean sequestration of carbon and for harvesting biomass. I referred to the adaptability of Australian meat consumption choices: per capita consumption of high-emissions products (beef and mutton) had fallen, and of low-emissions products (chicken and pork) had increased markedly in response to price increases in the former and reductions in the latter over the past half century. A passing reference to reducing emissions by partial return to traditional Australian patterns of meat consumption – substituting some zero-emissions kangaroo meat for high-emissions beef and lamb, in production and consumption – received exaggerated but ill-directed attention at home and abroad.

Research and regulatory development was warranted, to make the most of opportunity for mitigation in farming and land use.

The Carbon Farming Initiative was legislated in 2011 alongside the Clean Energy Future package. These arrangements were carried into the Abbott, Turnbull and Morrison governments' Emissions Reduction Fund (ERF). The ERF was a clunky,

truncated and less adequately funded version of the emissions-trading-scheme-linked Carbon Farming Initiative. It required resources from general revenue, rather than from sales of emissions permits. Clunky or not, Abbott's ERF kept alive the sale of offsets as a way of providing incentives for farm-sector carbon sequestration. The arrangements developed by the Clean Energy Regulator showed how an offsets scheme related to land use could work, and that there was strong private response to incentives.

It has only become clear since 2011, at least to me, that Australia's potential strength in low-cost production and use of biomass can provide the most cost-effective path to zero-emissions production of many manufactures from chemical processes. This is necessary to end emissions from gas, oil and coal used in chemical manufacturing processes. Capacity to produce low-cost biomass can be a source of Australian comparative advantage in zero-emissions industry.

Recent IPCC reports, most importantly last week's report on agriculture and land use,[4] have elevated the importance of natural climate solutions to achieving global mitigation ambitions. Sequestration of carbon in soils, pastures, woodlands and forests can make a major contribution to holding temperature increases significantly below 2°C and as close as possible to 1.5°C.

Expansion of knowledge in all these ways points to the need for transformation to reduce the size and weight of the human footprint on the planet: to consume less land- and emissions-intensive food, including through reducing consumption of red meats; to reduce the amount of land under cultivation; to increase forested areas and their diversity; to economise on use of water; and to do this while drawing on biological sources of the chemicals for industrial processes that were previously supplied by coal, oil and gas.

At the same time, knowledge has been expanding about how we can achieve these outcomes: knowledge of nutritious and palatable substitutes for old foods that have less damaging ecological impacts; knowledge of farm and land management systems to improve the trade-off between environmental cost and value in use; knowledge of regulatory arrangements that can encourage the necessary transformation.

There is rising awareness of the need for fundamental change, and the beginnings of knowledge that fundamental change is feasible. The short-term costs of change in some of these areas are still high, but increases in the scale of the new are starting to bring costs down. Transformation is unfamiliar, and daunting, but beginning.

The decarbonisation of electricity and the electrification of industry and transport can remove about two-thirds of global emissions. The land use, agriculture and food transformation can deliver most of the rest. Meinshausen and Dooley (2019) have shown that we can get most of the way to the global Paris goals through renewable-based electrification and the land use transformation.

[4] *Climate change and land*. IPCC, August 2019.

Australia is uniquely well placed to lead and prosper from the land use transformation, just as it is in energy. As with energy, Australia's own transition in managing land should be seen in the context of global opportunity.

The land use mitigation opportunity and agriculture

Australia stands out amongst developed countries and globally for its large endowment per person of woodlands and forests. This gives us massive advantages for carbon sequestration and for production of biomass for industrial use.

Sequestration potential is affected by rainfall. The applied atmospheric physics is still coming to grips with the effects of warming on rainfall in particular locations. In the world as a whole, average rainfall rises but the distribution changes. Scientific advice to me in 2008 and 2011, reported in the Reviews, said that southern Australian latitudes were likely to experience lower rainfall, and, on the whole, northern latitudes higher. This pattern is largely supported by subsequent work.

The southern latitudes have long been the source of most Australian agricultural value. With agriculture challenged by the combination of drying and warming, there will be shrinkage in the area of cultivation. Newly submarginal farmland may be more productive as a source of carbon sequestration and biomass. Wetter northern areas will be able to sustain more intense concentrations of living plants, making them potentially larger sources of biomass for harvesting or long-term carbon sequestration.

The 2008 Review set out in Table 22.2 the main opportunities for large-scale sequestration in changed land use.

Most discussion of sequestration potential has focused on fast growing plantations in higher rainfall regions that are suitable for relatively intensive agriculture. That undersells the potential for abatement via changes in land use.

The general story is of immense potential for storing more carbon in the vast rangelands – but of great uncertainty about the potential and what is needed to secure it. Research to define the possibilities and how to access them more closely would have great value. To maximise value of production from this land across all possible uses would require a reward for carbon sequestration, and separate fiscal incentives for biodiversity. It would leave landowners to judge how much of their land should be subject to destocking for sequestration and biodiversity purposes.

The mallee is a eucalypt marvellously adapted to the fire-prone arid Australian environment. The mallee trunk grows beneath the land surface, where it is not affected by fire. A bushfire can consume the multiple branches, and with leaves sprouting from the trunk below the surface the branches will quickly grow again. This allows regular harvesting for processing of large tonnages every four years. Sequestration continues through increases in the mass of the trunk (the 'mallee root') while the branches and leaves provide a periodic harvest of biomass.

Savannah covers about one-fifth of the Earth's surface. Much of northern Australia is covered by savannah. The savannah country generally is experiencing increased rainfall, and this is supporting more dense vegetation there. This change is happening naturally, and there are opportunities for human intervention to increase the carbon stock.

The large land area and increased rainfall of the Australian savannah warrant systematic research on defining and utilising such immense carbon sequestration potential. Yet the general story is of immense potential for sequestration of carbon through changes in Australian land use, but of small and diminishing effort to define the potential and the means of unlocking it.

There is considerable potential for emissions reductions through use of agricultural, woodland and forest output for bioenergy production. In the zero-carbon economy of the future, however, biomass is likely to be reserved, by its price, for high-value uses in civil aviation and inputs into chemical industrial processes. The value would be large, but it may not contribute directly to reducing Australian emissions as it replaces emissions from fossil energy throughout the world.

The food challenge

The twenty-first century has seen strong economic growth in developing countries even as incomes have stagnated in developed countries since the global financial crisis. In developing countries, rising incomes have led food consumption patterns to move rapidly towards those of the rich. Meat consumption in China rose more than tenfold over 40 years of reform and development, to almost 70 kg per capita per annum, or about the average of the developed countries. Chinese consumption is dominated by non-ruminant meats – pork and chicken – which are more efficient in converting grain into animal protein and do not emit methane from enteric fermentation, but nevertheless place great pressure on land and the natural environment. Chinese direct and indirect demand for grain has pushed up global prices and reversed a strong tendency through the second half of the twentieth century for food prices to fall.

South Asia, with its religious and cultural constraints on eating meat (particularly beef) will not see levels of meat consumption similar to those in China. But the pressures on land resources will still be large. Successful development in Africa is also likely to place similar pressures on food production and the natural environment.

The extension of something like the developed world's pattern of food consumption to the whole of humanity with successful global development in the twenty-first century is inconsistent with climate stability, and more generally with the stability of ecological systems. It would also be unhealthy.

The convergence of economic development, climate, biodiversity and general ecological and health imperatives will create strong momentum towards changes in global diets. Rising absolute and relative prices of meat in general and especially ruminant meat will modify consumption patterns.

Changing personal preferences will play an important role. The health story will become more influential everywhere – following trends amongst better educated and higher income people in the developed countries. Larger numbers of people in high-income nations will be influenced by the climate, general ecological and animal welfare cases for greater reliance on plant-based foods.

And changing personal preferences, relative prices and technological opportunity will open the way to a revolution in production of meat-like substitutes from plant biomass. In taste, texture and nutrition these will become indistinguishable from meat from the killed animal – superior in nutrition, if that is preferred. The price of substitutes will fall, eventually, to below the rising price of farm-based meats.

More generally, there will be a shift in demand to higher quality, safer and more expensive food. Australia has exceptional comparative advantage in supply of the higher value products that will dominate demand – especially in supplying the world's largest and most rapidly growing markets in Asia. The main meat substitutes make intensive use of biomass and energy and less use of water than the animal competitors. Australia is well placed as a supplier to international markets, especially to what will become the main centre of global demand, Asia.

Capital and expertise will be more important, and water less so, in food production. This will enhance Australia's advantages in this new food world.

Carbon Farming Initiative, Emissions Reduction Fund and the international rules

From Kyoto to the Paris Rulebook

The 2008 Garnaut Review concluded that full realisation of the potential for mitigation in the land sector required comprehensive carbon accounting. The inclusion of land under the Kyoto Protocol framework was incomplete. With the adoption of the Paris Agreement in 2015, and the subsequent implementation rulebook adopted at the end of 2018, all countries will be required to report emissions under the same UNFCCC reporting framework, applying the latest IPCC guidance, which includes a more comprehensive approach to land-based accounting.

Key elements of the Paris Agreement raise the possibility of unprecedented reliance on land-based mitigation. While reliance on land-based mitigation in the Kyoto Protocol was subject to strict limitations and caps, in the Paris Agreement land-based sinks are now prominent (Dooley and Gupta, 2017).

From the Carbon Farming Initiative to the Emissions Reduction Fund

The Carbon Farming Initiative allowed farmers and land managers to earn Australian Carbon Credit Units (ACCUs) which each represented one tonne of carbon dioxide equivalent (CO_{2e}) reduced by storing carbon or by reducing GHG emissions on their land. The ACCUs could be sold to clear obligations under the carbon-pricing rules. In July 2014, the carbon price was repealed. On 31 October 2014 the new Coalition government's climate strategy, the Direct Action Plan, was passed as part of the *Carbon Farming Initiative Amendment Bill 2014*.[5] The 2014 amendment established the Emissions Reduction Fund to provide a transition for the Carbon Farming Initiative by amending the *Carbon Credits (Carbon Farming Initiative) Act 2011* to provide for the Clean Energy Regulator to conduct auctions and enter into contracts to purchase emissions reductions. The 2014 amendment therefore oversaw a shift from a carbon price to government-purchased abatement, and an expanded Carbon Farming Initiative, moving eligible projects beyond the land sector to include energy and transport. In the ERF, $2.55 billion was made available for direct purchasing of abatement under the reverse auctions, of which $226 million remained in May 2019. The Government's Climate Solutions Fund was announced on 25 February 2019 to appropriate an additional $2 billion from 2020–21 onwards to fund auctions to 2030.

Agriculture and land use were spared the general removal of incentives for reducing carbon emissions under the Abbott–Turnbull–Morrison governments by the establishment of the ERF. This kept alive important features of the Carbon Farming Initiative, including its administrative framework.

Growing the future

It is now clear to the international community, as it was not 11 or 8 years ago, that changes in land use and agriculture will have a central role in avoiding high costs of climate change. Perhaps two-thirds of the global movement to zero emissions will come from decarbonisation of electricity and electrification of transport and industry. Nearly all of the remainder will come from changes in agricultural and pastoral activities and land use, with some help from decarbonised energy. If we move too slowly and overshoot the Paris targets, plant-based carbon sequestration – including through the capture of carbon wastes from plant-based industrial processes and storing or using them in ways that keep them out of the atmosphere – will be the main avenue for achieving negative emissions.

The transformation of food, agriculture and land use that is necessary for climate change mitigation is also necessary to allow the maturation of global development, to improve human health, and to maintain a stable global ecology

[5] http://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/Bills_Search_Results/Result?bId=r5280

more generally. There will be one agricultural and land use transformation to serve these four great purposes.

It is now clearer to me than it was 11 or 8 years ago that Australia has great advantages in this new zero-emissions world. The opportunities for zero- and negative-emissions land use lower the cost of doing our fair share in a global mitigation effort, and open new areas of comparative advantage in a zero-emissions world economy.

To make good use of this opportunity, Australia will need to put in place systematic incentives for reducing emissions in agriculture and land use, and provide good reasons to believe that they are here to stay. And it will need to restore old national strengths that have been allowed to decline in recent years: namely, our strengths in research and education on agricultural, pastoral, forestry and related industrial activities. The combination of low-cost renewable energy and abundant land for biomass will be powerful in the synthetic food production industries in a zero-carbon world.

Alongside our industrial opportunity in renewable energy, our strength in growing and using biomass will set Australia up as the 'Superpower of the low-carbon world economy'.

To conclude: a forecast

The low-carbon world economy will be especially favourable for rural and provincial Australia. Energy will be produced mainly outside the large cities, much of it in remote locations. This will make it commercially attractive to process many Australian mineral, agricultural and pastoral products into higher value, close to the places in which the basic commodities are produced. A new carbon farming industry, prospering exceptionally in less agriculturally productive regions, will add substantially to rural incomes. Biomass will have additional value as a base for new industry, especially when combined with low-cost energy. The new activities on average will make fewer demands on water than the old. And low-cost energy will improve the economics of recycling, desalinating, transporting and otherwise increasing the value of limited water resources.

Rural and provincial regions will be the engine room of the 'Superpower of the low carbon world economy'.

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Ross Garnaut AC is an economist whose career has been built around the analysis of and practice of policy connected to development, economic policy and international relations in Australia, Asia and the Pacific. He was Distinguished Professor of Economics at The Australian National University and currently holds a part-time research position as Professorial Fellow in Economics at the University of Melbourne. He is the author of many influential economics books and papers. Ross held positions as Chairman of the Boards of large Australian and international companies continuously from 1988 to 2013. He has held a number of senior Government positions, including as head of the Financial and Economic Policy Division of the Papua New Guinea Department of Finance in the years straddling Independence in 1975; principal economic adviser to Australian Prime Minister Bob Hawke; Australian Ambassador to China (1985–88). He has led many high-level Government Reviews and Commissions, including the preparation of the Report to the Australian Prime Minister and Foreign Minister 'Australia and the Northeast Asian Ascendency' (1989); the Review of the Wool Industry (1993); the Review of Commonwealth–State Funding (2002); and the Garnaut Climate Change Reviews (2008 and 2011). He was Chairman of the Australian Centre for International Agricultural Research 1995–2002 and Trustee and Chairman of the International Food Policy Research Institute 2003–10.

Can we feed the world without wrecking the environment?

Professor Sir Charles Godfray FRS
Oxford Martin School, University of Oxford

Abstract

It is now over 200 years since Malthus pessimistically predicted demand for food would inevitably outpace our capacity to produce it. Over these two centuries the goal of feeding the world sustainably has seemed elusive and even receding as we understand the threats posed by global warming and other types of environmental challenge that John Beddington so memorably called the 'Perfect Storm'. But there are grounds for hope. Population growth rates are decelerating as more countries go through the demographic transition. We can now imagine a future where humanity's demands of the Earth plateau or even decrease. But at that plateau there will be billions more people needing to be fed than exist today. This talk argues that it is possible to feed this number of people without despoiling the environment, but only if we make hard decisions today. We require a new revolution in agriculture, of the same magnitude as the Industrial and Green Revolutions, that not only boosts productivity but also radically improves resource-use efficiency and sustainability. We need to reduce waste across the food system. We need to make hard decisions about diets and consumption patterns. And we need to accept globalisation and refashion a globalised food system that provides public as well as private benefits. These ambitious goals are attainable – it's 'game on' – but only if we understand the risks and the challenges and build the political will to act.

Malthus, famously, at the end of the 18th century wrote in his essay on populations about the inevitability at some time, as he saw it, of population outgrowing food supply. Malthus predicted that during the early decades of the 19th century there would be widespread famine. That famine did not happen, because of the Industrial Revolution, which was a technological and a social and economic advance, also associated with new methods of rural production, sometimes called an agricultural revolution.

The next wave of Malthusian pessimism was in the 1960s and 1970s, associated with movements such as 'Limits to Growth', 'the Club of Rome', and Paul Ehrlich's very influential book *The Population Bomb*. Rereading that recently, with modern eyes, I found it an extraordinary book in its pessimism that democracy would disappear in Europe by the end of the 20th century. That did not happen either, largely because of the Green Revolution, the advances in the technology around plant genetics and food production.

At the moment I think we are going through a third wave of Malthusian pessimism, which my friend John Beddington memorably called the 'Perfect Storm'. It differs from previous episodes of Malthusian pessimism, especially in its global scope.

This paper has been prepared from a transcript and the illustrative slides of the presentation.

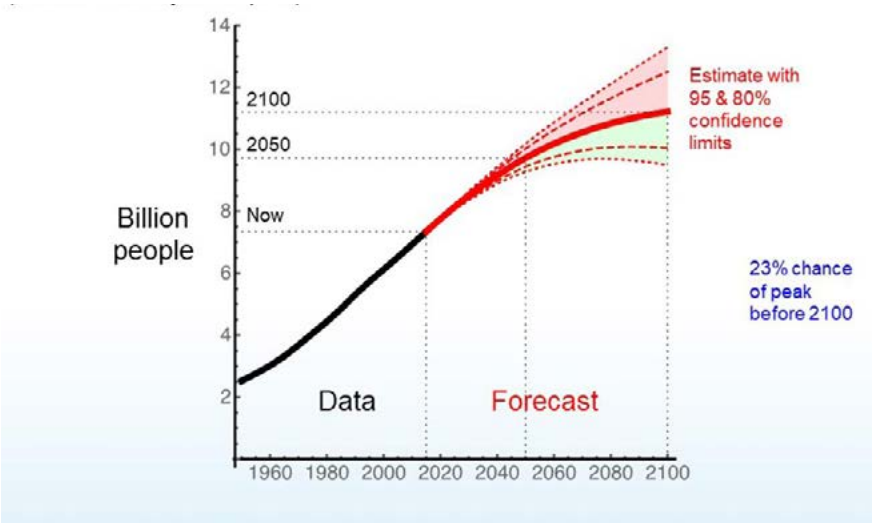

Figure 1. Estimated future population growth assuming medium fecundity. Source: *World Population Prospects*, *2015 Revision*. UN Population Division.

I like to tell my students that at age 60 I am more positive about the future than when I was in my 20s. That is largely because we know that human population increase can be slowed, if we eliminate poverty, provide access to reproductive healthcare, and educate children – especially girls. It is intellectually possible today to say that there is a counter argument to Malthus which didn't exist when I was a student, 35 years ago.

It will be a challenge to feed a global population of 10 billion or 11 billion (Figure 1), but at least we can conceive of a time when the demands of humanity on the planet to produce food will plateau, or even decrease.

However, the pressures on food supply do not come just from population increases but also from demand for more varied and acceptable food. Figure 2 shows increases in meat consumption up to now, and projected global increase in meat consumption into the future. As people come out of poverty they will demand, understandably, a richer and better diet. These types of diet typically have a greater environmental footprint.

Thus we will face for at least the next 30–40 years the challenge of continuing demand growth. This demand growth will be increasingly urban with the challenge of feeding an increasing number of mega-cities in the global south. Though progress has been made on hunger, numbers are increasing again, largely because of civil strife and low-level wars – new types of conflict that we have not seen before. Progress has not been as fast as hoped on ending micronutrient deficiencies, and we face a rising epidemic of the diseases of over-consumption – the obesity crisis.

There are challenges on the supply side too. Agriculture faces increasing competition for water and land, and from soil degradation due to unsustainable production methods. And we will see an increasing frequency of shocks; some

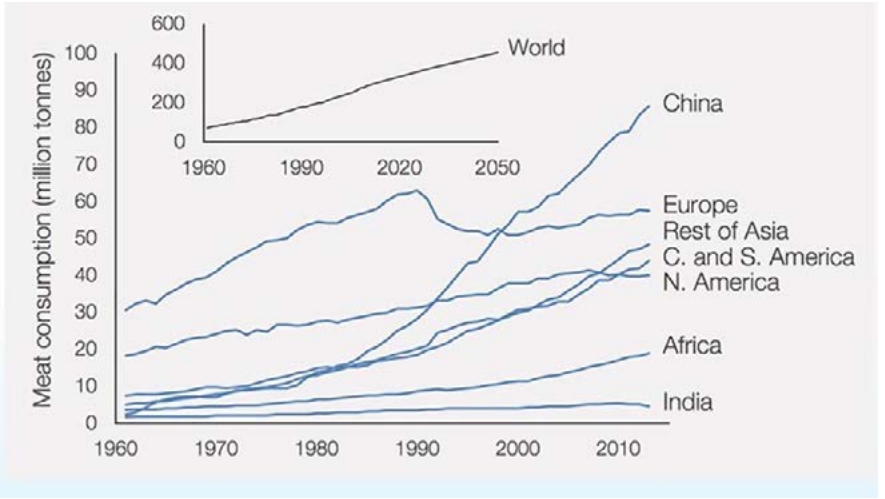

Figure 2. Current regional and projected global meat consumption.
Source: Godfray et al. 2018. Data from www.fao.org/faostat/en/?#data.

associated with climate change and some geopolitically, such as the challenges to global trade systems we are seeing at the moment.

What if we eat healthily?

'Win–wins' are often scarce, but healthy eating is one approach that I think offers some genuine 'win–wins'.

What if we were to assume that by the year 2050 the world's population will have adopted regionally appropriate diets as recommended by the World Health Organization's nutrition guidelines? This is a hypothetical question, but useful for exploring the scale of potential gains if the world were to change in this way.

I am part of a team led by Marco Springmann that has modelled this transformation and calculated its effect on the numbers of diet-related deaths and on greenhouse gas emissions, and we have begun to explore the associated economics (Springmann et al. 2016).

The first result is that if globally everyone were to transition to healthy diets by 2050, there would be 5.1 million fewer avoidable deaths per year (Figure 3, top). On the map the darker colours are where there are more avoided deaths per capita. There tend to be more in high-income countries reflecting the fact that today many diet-related diseases are problems of over-nutrition – of being overweight or obese.

As well as the clear global health advantage of switching diets, Figure 3 shows a significant environmental benefit in reduced greenhouse gas (GHG) emissions. On our current path we expect GHG emissions from the food system to increase by about 50% by mid-century, but in our hypothetical dietary shift for purely health reasons, the associated food-system emissions would increase by only 7%. We need to do much better than this but it shows the potential there is, just through dietary change, for helping maintain this planet within stable climate limits.

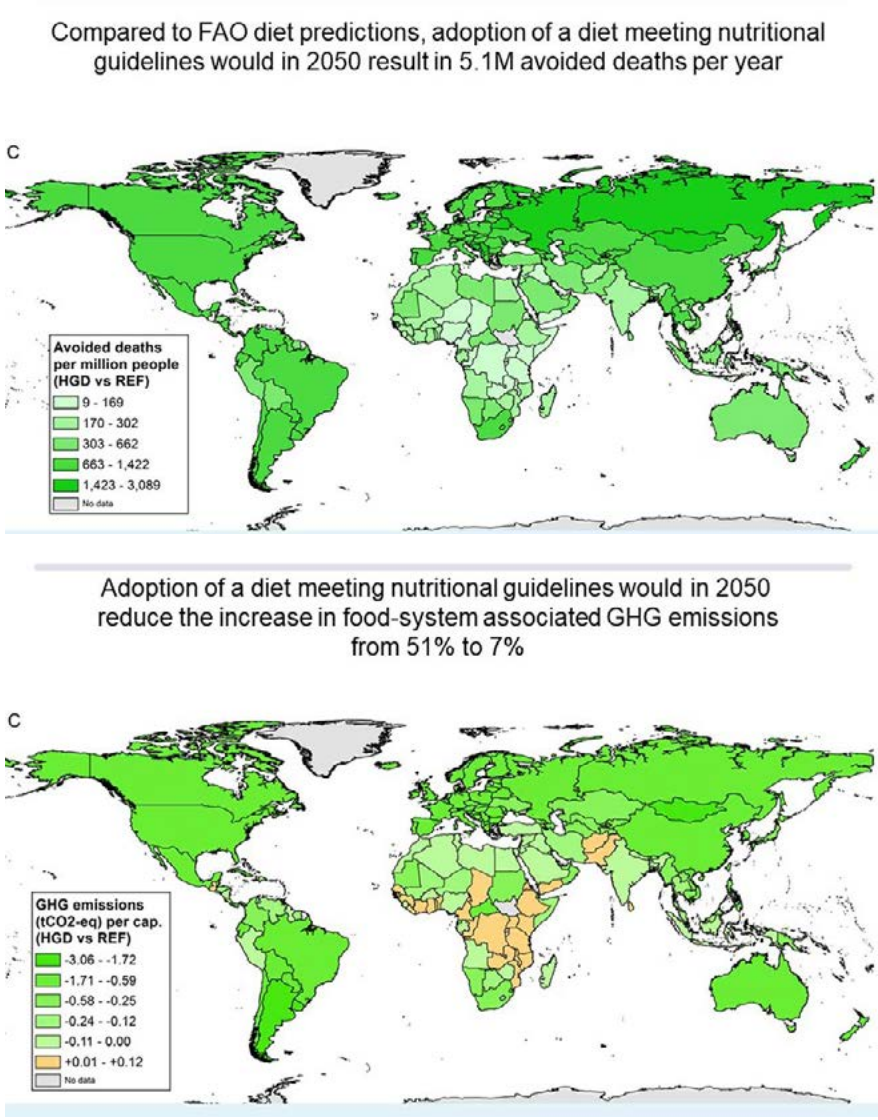

Figure 3. Global healthy eating effects (modelled and calculated) on deaths (top map) and greenhouse gas emissions (lower map).

We also found economic benefit during our analyses. Part of that came from the significant direct benefits of fewer diet-related deaths, in term of healthcare costs and time off work. Overall, hypothetically, there is a clear argument for multiple wins (health, climatic, economic) from healthy eating.

Can we feed the world within planetary boundaries?

Marco Springmann, at Oxford, has also led a team examining options for keeping the global food system within planetary boundaries (Springmann et al. 2018). What sets of solutions maintain a safe operating space, and what does that space look like? What are the contributions of different types of agriculture

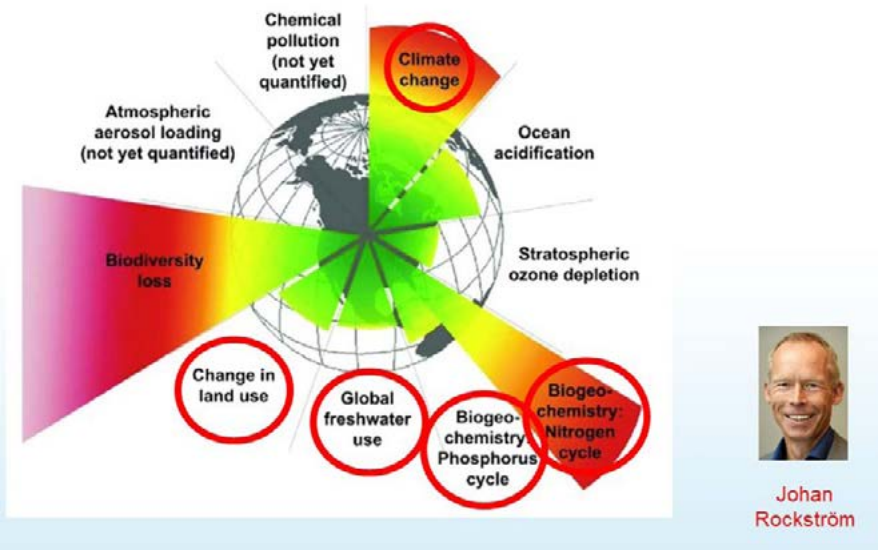

Figure 4. Planetary boundaries.

to breaching these planetary boundaries and what might be possible to do about that?

Planetary boundaries (red circles in Figure 4) were proposed by a team led by Johan Rockström, now at Potsdam, and Will Steffen (ANU). They are notional safe limits, safe boundaries, that would prevent really serious environmental catastrophes in the future. The Springmann team looked at the threats to the climate change boundary (represented by extent of GHG emissions) from various types of agricultural production: staple crops, legumes, and animal products. For GHG emissions using 2010 data, animal products contributed the greatest threat or pressure, with staple crops coming second (Figure 5).

We then repeated that analysis for all five planetary boundaries using the most recent available data (for 2010) and projecting for the year 2050. Figure 6 shows the sectors of agriculture that are having the greatest effect on each boundary.

The analysis also shows tensions. The green bar represents fruit and vegetable production. Eating more fruit and vegetables is good for health but is the second largest pressure (after staple crops) on freshwater use.

Can we lessen the effects of food production on planetary boundaries?

Can we help reduce the environmental impacts through increased investment in technology such as agronomic practice, and food processing research; or through increased investment in preventing food-loss and waste; or through diets or through socio-economic measures? We tested this using econometric analysis and Figure 7 shows again the large potential to reduce GHG emissions through dietary change (FLX stands for 'flexitarian'). For the other planetary boundaries, most opportunities come from a combination of investment in technology and waste/food-loss management, as well as changing diets.

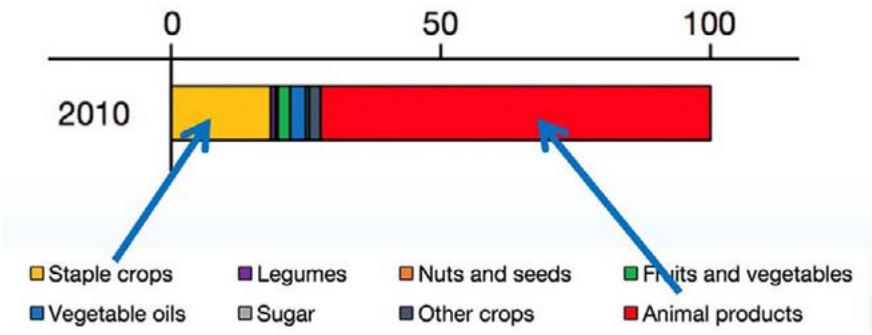

Figure 5. Percentage contributions of different sectors to total agricultural greenhouse gas emissions.

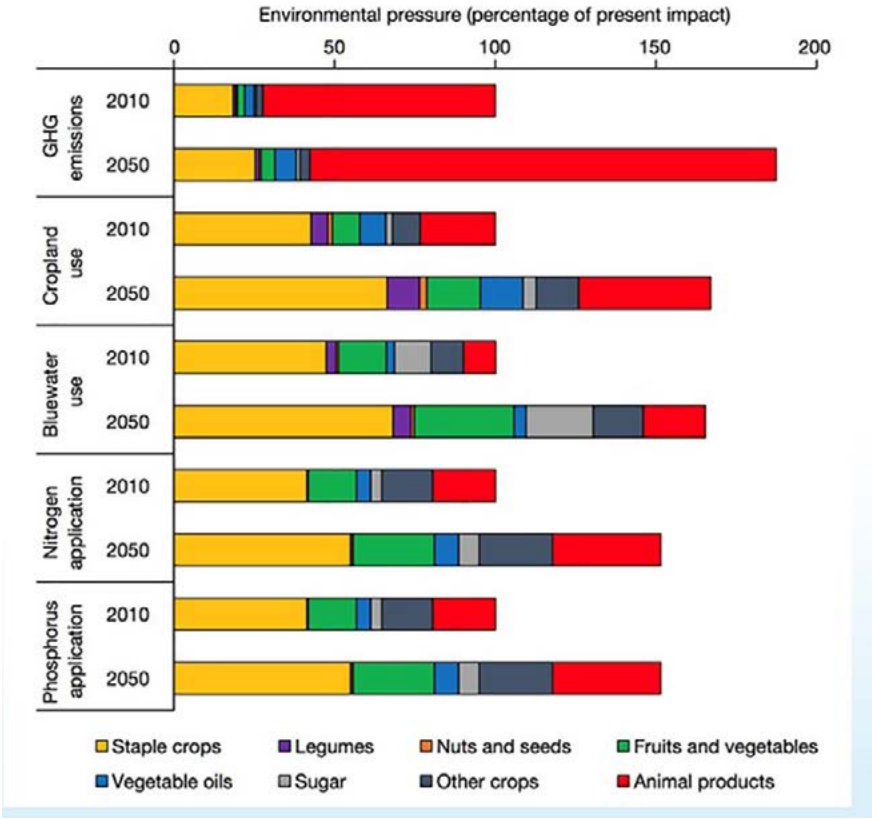

Figure 6. Comparison of environmental pressure on planetary boundaries (as a percentage of present impact) contributed by various agricultural sectors: data from 2010 and modelled for 2050.

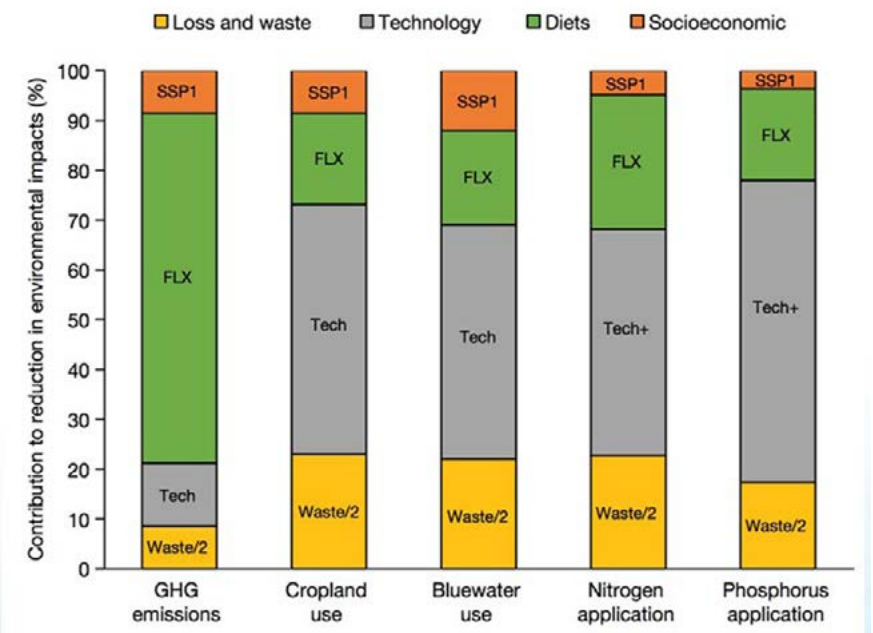

Figure 7. Potential avenues (dietary, technological, waste/loss management, socioeconomic) for reducing the environmental impacts of food production on planetary boundaries.

Near-term governance challenges

There are some near-term challenges I find particularly worrying.

Figure 8 shows the percentage income spent on food for a selection of countries. In low-income countries such as Cameroon, Belarus, Egypt, a major part of family income is still spent on food. For countries such as UK and USA, families typically spend about 10% of their income on food.

More and more people are living in cities. Over half the world's population lives in a city and many of the fastest-growing cities are in sub-Saharan Africa, India, China and SE Asia, and South America (Figure 9). I do not think this fact gets sufficient policy attention. Figure 10 shows developing-country cereal trade: the amounts that the sector exports are dwarfed by the amounts of imports. Feeding the urban mega-cities of the global south requires a well-functioning global commodity sector that can transfer food from countries with a surplus to those with a deficit. If we get this wrong then we will see movements of people and forced migration that will dwarf what we have seen recently with huge humanitarian consequences.

Global commodity markets are largely run by the private sector, and may have the flexibility and adaptability to cope with future shocks. But I think they need stress-testing – we thought we had a very well-functioning global banking system in the years up to 2008 and now rue the fact we had failed to do insufficient stress-testing. This call shouldn't be seen as criticism of the major

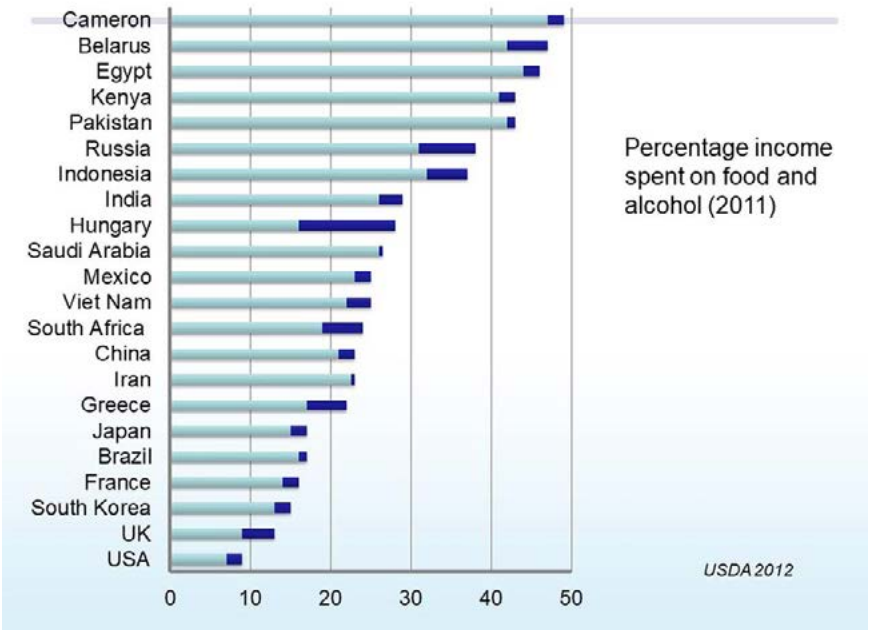

Figure 8. Greatly varying family-expenditures on food. Source: USDA 2012.

companies that run the trade in global food, but as a plea to build resilience into global food systems.

I began by saying how first the Industrial and then the Green Revolution brought to an end the first two episodes of what I have called Malthusian pessimism. I think we now need a new revolution. I very much like the narrative of my friend Sir Gordon Conway, of Imperial College London, who has argued for a Double Green Revolution: yes, increasing productivity, but also increasing the efficiency of resource input use and dramatically reducing the environmental footprint of

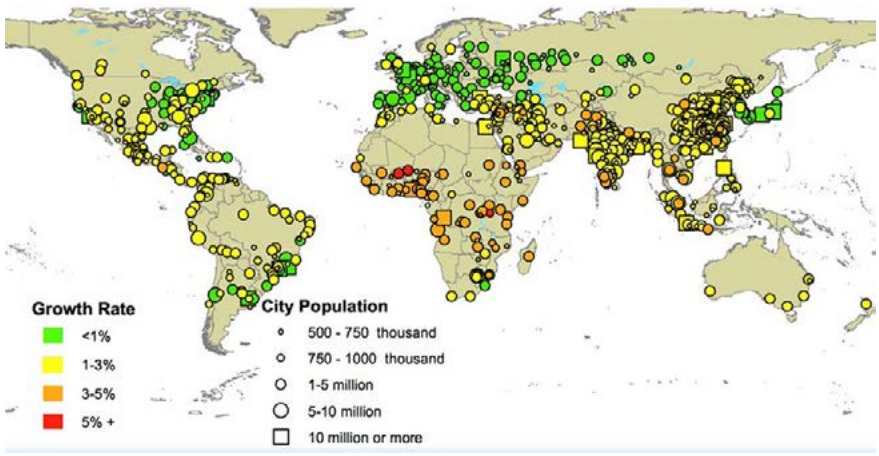

Figure 9. Distribution of large global cities and their growth rates.
Source: *World Urbanisation Prospects*. UN Population Division.

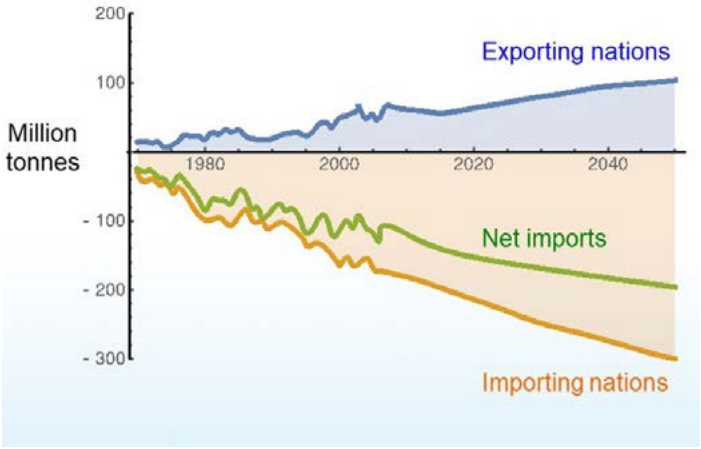

Figure 10. Cereal trade in developing countries: imports and exports. Source: FAO (Alexandratos & Bruinsma 2012, Figure 1.5).

food production. And unlike the Industrial Revolution and the Green Revolution, this revolution also requires radical changes on the demand-side of the food system, the way we invest and retail food, and the diets we choose to eat.

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Charles Godfray is a population biologist with broad interests in science and the interplay of science and policy. He has spent his career at the University of Oxford and Imperial College and is currently Director of the Oxford Martin School and Professor of Population Biology at Oxford. His research has involved experimental and theoretical studies in population and community ecology, epidemiology and evolutionary biology. He is particularly interested in food security and chaired the UK Government Office of Science's Foresight project on the Future of Food and Farming and is currently chair of the UK's agricultural and environment (DEFRA) ministry's Science Advisory Council.

Q&A

Chair: Andrew Campbell
Panel: Sir Charles Godfray

Chair: Andrew Campbell
To kick off this Q&A session: with food commodity markets, you're going to starve a country for a little while and see how they go?

A: Sir Charles Godfray
I think one would try and do it exactly as one stress-tests the banking system. One would want to know what would happen if there was a real failure of, say, multiple bread baskets; whether the largely private companies involved have both the logistic and the financial capacity to withstand that stress. That's best done by a paper exercise. It's hard, and this is no criticism, because the international grain commodities are largely controlled by the private sector, and of course the private sector companies don't want to have all their data in the public domain. You could argue about how successful the exercise is within the banking sector, but I think something needs to be done similarly in global commodity trading.

Chair: Andrew Campbell
And could you ruminate for a moment on potential impacts on UK science and scientific collaboration, UK aid policy and UK climate change policy, of Brexit?

A: Sir Charles Godfray
I worry about crashing out of the largest trading block in the world and going onto World Trade Organization (WTO) rules if it's a no-deal Brexit. I worry immensely about what that will do to our farming sector. For example, I cannot see any good way out for sheep farmers in the UK if we're thrown into the WTO. However, I think it's wrong to say that everything will be terrible. Science is a real issue as much science funding comes from the EU, but I suspect science will be relatively easy to sort out, compared with many of the trade issues.

Q: Colin Chartres, The Crawford Fund
Last October we had Shenggen Fan, head of IFPRI, here and he was the first person I had met who told me that he'd eaten artificial meat. If, for example, in 20 years' time, 50% of the world is eating artificial meat, has anyone started modelling some of this data, looking at the impact that's going to have? Have we started any serious work in that area?

A: Sir Charles Godfray
My group did try to model different scenarios for a report for the World Economic Forum. One of the issues is that it is relatively easy to make assumptions about the effects of a transfer to plant-based meat substitutes. It's much harder when you think about cultured meat. In most cases, greenhouse gas emissions from cultured meat are actually higher than they are from normal

This Q&A report has been prepared from a transcript.

meat, though that would change as it went to scale. I have changed my mind over the last four or five years, from thinking that it was unlikely to have a major effect in the next decade. I think it will also have an effect on feed. Despite being an entomologist, I find it hard to believe that humans will ever eat large amounts of insects, but I think insects could be a really important protein source for livestock, especially in developing countries.

Q: Female
Good morning and thank you very much for your presentation. I am a sheep farmer from up the road; I also work for the Centre for Global Health Security at Chatham House. My first question is a comment: the German Nutrition Society has put out a statement concerning the need for vitamin supplements for some vegan or vegetarian diets. I think these issues need to be talked about, because there are groups of people, particularly women and children, who need very precise supplements, and we know the consequences to their life chances for economic vegans in low income or low resource settings.

My second question is on the modelling. I know Marco Springmann's work and I really appreciate his passion. Would it be possible for the modelling to start to take production systems into account? Looking at different greenhouse gas emissions, plus the other planetary boundaries, in relation to opportunities for carbon sequestration, and the role that animals play in maintaining healthy environments? Is it going to be possible for Marco and his group to be modelling how to meet nutrition requirements in particular geographical settings?

A: Sir Charles Godfray
Let me answer those in reverse order. Marco's approach does currently include some different production systems. And I know that Mario Herrero's group in Queensland is also working on that, and I agree that it is important. Your first question was on nutrition, and I think your point about vegan diets is fair. It is perfectly possibly to eat healthily without eating meat, though I suspect that you have to be a bit more careful to ensure you get all the micronutrients you need. However, I don't think there are nutritional arguments about calls for flexitarianism, but I agree that there are warnings that you should be careful when you move to a purely plant-based vegan diet.

Q: Male
Thank you, Andrew. Thank you to Charles. That was a very comprehensive and tight presentation, which seems to cover all the bases from top down. As an agronomist I find more satisfaction in looking at things from the bottom up – from country level up – the system level up. The next 20 or 30 years is when it's all going to have to happen, which tends to put climate change on the back-burner. In sub-Saharan Africa, the population is growing at 2.6% per annum, and it's totally dependent on imported foods; there is a yield gap of the order of 200–300% in potential yield relative to actual yield. We have the technologies. It is the institutional problems, the structural problems and government problems that are going to have to be solved in that situation.

The rest of the world, I think, is more or less OK. Green Europe's up there doing its own thing; it is, I think, becoming less relevant for the world. The New World

Professor Sir Charles Godfray FRS during his Keynote address in the Great Hall of Parliament House.

will feed the world, that's how I see it. If you look at sub-Saharan Africa, we have some optimism there: for example, Ethiopia's doing very well.

A: Sir Charles Godfray
There are many really interesting points there. I do agree with you that much of the action around food security and whether we achieve global food security is going to be in sub-Saharan Africa. I visited Ethiopia for the first time 18 months ago and it is extraordinary what's happened there and I think reinforces your point. Certainly, analysis from our Overseas Development Department in Oxford, which does a lot of work in Ethiopia, has shown the benefits from the mere fact that you have, even in quite small rural towns, banks with expertise in local lending. So I think there are encouraging signs in other parts of Africa – but for every example such as Ghana, Ethiopia, there are other examples of countries that are not doing as well.

I'm slightly less sanguine than you about climate change in the next couple of decades. The frequency of extreme events, which, as every farmer in the room knows, are the ones that hit production most, are increasing. Within our lifetimes I fear that we're going to see them affecting all sectors, including the agricultural sector. I'm really impressed by how the agriculture sector in many countries is stepping up to this; for instance, the National Farmers Union in the UK has set an ambitious goal of reaching net zero greenhouse gas emissions across the whole of agriculture in England and Wales by, I think, 2050. So while I largely agree with your points, I worry about climate change. We really do have to take action sooner rather than later.

Q: Eric
In terms of revolution, in our democratic market there are societies where individual agency and freedom is highly valued. Which sort of innovative policy ideas can you offer to achieve that?

A: Sir Charles Godfray
That's a very good question. We live in a free market, but it's not an unlimited free market and we as society decide to put structures around our free markets. The challenges aren't so much economic as in the political economy sphere. We can already see social norms changing. We are seeing that people are beginning to think much more about what they consume. We are beginning to see people asking really interesting questions about the private sector and the purpose of the private sector. The way we have chosen to run our private sector isn't the only way to run a private sector. I think some of the economic theory that underlay that as a perfect way to run a private sector, largely from the 1980s, is now being challenged by modern economic theory. Recall the old joke that people don't change their minds but they die leaving new people with new ideas, and I suspect that there might have to be a similar transition in thinking about economics. But I think there are possibilities in all those areas: in the role of government, in setting the boundaries around which markets work, and in the social norms that drive us as individuals.

Q: April, University of Sydney
Thank you for your very informative talk. And as conveyed in your slide, now people are spending 9–10% of their income on food, and last year a paper said that Americans are spending 6.5%, which is really low. Considering these new planetary boundaries, can you see whether income output on food will increase or decrease in the future?

A: Sir Charles Godfray
That's a really great question. Let me first give an over-simplistic answer to it. Environmental economists often say we should internalise the cost and that would mean food prices would go up and that would be a good thing as they'd go up differentially. It's all very well for a well-paid professor to say that, because if steak increases and doubles in price and I still want a steak I can still afford it. But the poorest decile or two in a country won't be able to do that. To me, it's a straight question of politics. And of course, and again this is a simplistic answer, what one would ideally do is to set up proper safety nets.

If anything, we're moving away from safety nets, and another great challenge ahead in this century – apart from the food system and climate change – is the growth of inequality. We know capitalism works; we know capitalism is the only economic system that can raise all boats, but modern capitalism with the vast profits made by Internet platform companies, etc., looks like it has particular strong effects on increasing inequality.

So – I know there are politicians in the room – to me, that's one of the greatest challenges going ahead. And it's a long way away from food, but this is an area, I think, where it's very hard to think about food in isolation from how we choose to run our economy.

Q: Male
Thank you very much for the positive outlook. You don't see that too often nowadays when you're talking about calamity as we look forward. I'm really interested in your demand/supply analysis, and particularly the impacts of

urban growth. In the Sahel, in West Africa, we have been breeding crops for 40 years but haven't had much impact, mainly because there's no market supply mechanism. If we increase yields they're not going to find a market. The urbanisation story you gave there was really interesting. These regional centres, these big centres of population could become regional markets for local commodities. Do you see that as an opportunity, the regional markets around the urbanisation – not on the coastal areas, but in places like the Sahel?

A: Sir Charles Godfray
I do indeed. I think that's a really interesting point. I know it's quite extraordinary that in Mali and Burkina Faso, when mobile phones suddenly came in, prices became much more equal, almost overnight. It used to be the case that market prices varied hugely from village to village, town to town. Urbanisation in Africa can be this most tremendous force for good (I'm aware that there are some real experts on development in the room who should shout if they disagree with this) but it often fails to work that way because of issues around inadequate infrastructure, for example. Certainly, where I have worked in Kenya, the vegetable lorries crawl at a snail's speed up towards Nairobi and there is a real infrastructure challenge there.

Q: Female
Thank you, I enjoyed your talk a lot, especially the optimism in the long term. But having said that, I was curious about your concern about the short and the medium term. Do you see any relationship between the so-called third wave of Malthusian pessimism and the kind of political movements that we are seeing – towards conservative and right wing governments and popularism?

A: Sir Charles Godfray
Yes, I worry about that. I was talking rather glibly about changing diets, but if you talk about changing diets, some people will gain and other people will lose. I think also that people have lost out from globalisation, and it's because there has been insufficient care about those losers in globalisation that there is now social discontent, and that has given rise to some of the popularist movements.

Q: Mark Lawrence, Institute of Physical Activity & Nutrition, Deakin University.
I believe that in nutrition we don't engage sufficiently with the food security area. One of the issues that flies under the radar is around ultra-processed foods and discretionary foods – one of the biggest nutrition transitions that's happening around the world at the moment. It's ironic in a way that we give so much attention to red meat and those aspects, when often the vegan diets include very highly processed, ultra-processed foods. Just having a label saying 'vegan' doesn't mean it's nutritious.

A: Sir Charles Godfray
If I can make a comment on ultra-processed food: much of the food that's typically characterised as ultra-processed is quite horrible, full of the worst fats and the worst sugars. But if we look back at some of what are considered wonderful foods in the western tradition – cheeses and pickles and jams – they are processed foods too. I think there is value in concentrating on the nutritional

benefits of the foods. There is clear discontent with the economics of the food system, and sometimes terms such as 'ultra-processed' are used as a stick to beat the food private sector. To me, ultra-processed food is often but not always pretty awful but I worry that sometimes ultra-processed is used as a label and we forget it has both a nutritional and an economic component to it.

Q: John Angus
Let's consider rangelands and pastoral systems. If we stop producing meat, what happens to that land? Now perhaps it can be as, Ross Garnaut said last night, paid for by carbon credits. But in particular what happens to the community of herders and pastoralists who live there? What's to become of the rangelands?

A: Sir Charles Godfray
That's a really excellent question. Widespread livestock management is the only viable agriculture in much of the west of the UK. If I try and search for a silver lining to Brexit, it is that we will get out of the common agricultural policy and be able to think about new ways of supporting our rural communities. We need to think carefully about that. Livestock production provides multiple goods, and many of those goods are landscape goods around recreation, around carbon sequestration. An alternative for some areas may be for those lands to be managed differently so they support a much broader range of ecosystem services, which may still involve having livestock on them but at lower cost to the climate. Then we might achieve that 'Nirvana' of both maintaining vibrant rural communities and also having a much more environmentally friendly agriculture that is providing multiple public goods.

Q: Faruq, University of Tasmania
We looked at the very interesting slides on diet changes and the outcomes. Did you consider what to do in places where diets are culturally or traditionally very rooted, and how willing those people would be to change?

A: Sir Charles Godfray
A very brief answer to that is that we were assuming people would transfer to locally appropriate healthy diets, but we didn't assume anything about what might be the 'levers' of change that would be open to policy makers.

Q: Snow Barlow, The University of Melbourne
Building on John Angus's questions, would you care to speculate, globally, on the 'Ross Garnaut view', which was an Australian-centric view, of whether we can afford to continue to use what are currently agricultural lands, by and large, for food production?

A: Sir Charles Godfray
Thank you for that question. I thought Ross Garnaut's talk last night was absolutely superb. I think, the way to think about that is to focus on outcomes, and those outcomes will be the production of food, fibre and fuel. But we should also include the comparative advantage of producing a much broader variety of goods. When one is talking about comparative advantage, one does need

to think broadly, but in order for adjustment like that to happen, and for it to be politically acceptable, it must be done in a way that brings the people who actually work on that land along with it.

Chair: Andrew Campbell
It's been a great topic and great speakers. Charles, thank you for a fantastic opening to our day. We look forward to further interactions as the day goes on.

Sir Charles Godfray
And thank you all for some very good questions.

Weathering and halting the perfect storm: food system solutions

Dr Bruce Campbell
CGIAR Research Program on Climate Change, Agriculture & Food Security

Abstract

While the challenges of achieving the Sustainable Development Goals in low-income countries are immense, there are opportunities for significant advances and transformations, related to rising urban populations and changing food demands, digitalisation of the food sector, new ways of connecting farmers, and creative financial models. Climate risk management will need to be at the core of future initiatives. Several elements will need to come together to achieve the desired transformation, including meaningful policy and governance change, deepened private sector engagement with smallholders, and significant advances in digitalisation. Through such means, both adaptation and mitigation in agriculture can be tackled.

My focus is on smallholder agriculture. First, I'll address the mega challenges facing the food system. Then I will inspire you with the progress we are achieving, before ending with a sober reflection on what we need to do to achieve food system transformation.

The predictions for climate change impacts in Africa really frighten me. I am from Zimbabwe, which is shaded almost entirely in dark grey in the map (Figure 1) of places in sub-Saharan Africa where the lengths of growing seasons are forecast to change as the world warms. In the grey areas, seasons will be shorter than they are now if average air temperatures exceed 4°C above pre-industrial levels. Many parts of Zimbabwe are already really tough to farm, but

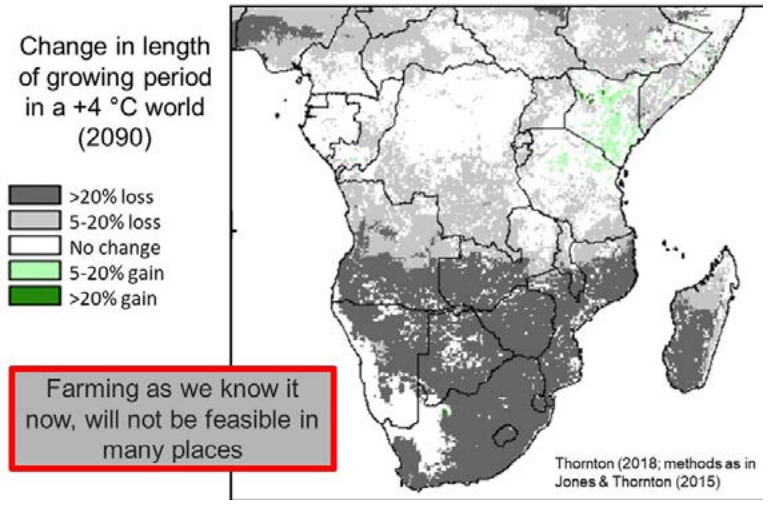

Figure 1. Shortening growing seasons pose a mega-adaptation challenge.

This paper has been prepared from a transcript and the illustrative slides of the presentation.

farming as we know it in those kinds of areas will just not be possible if growing seasons shorten by 20% or more. This kind of scenario would apply to my children's children at least. Even now, the number of record-breaking monthly temperature extremes is five times more than if the world wasn't warming (Coumou et al. 2013).

Putting that in another way, record-breaking events in sub-Saharan Africa in terms of drought have increased by up to 50% already (Lehmann et al. 2018). In some places in the world, we have only 11 growing seasons left to reach 500 million smallholder farming households, and the task of reaching those – in terms of building resilience – is enormous. As Figure 2 shows, we have to do something within the food sector to reduce greenhouse gas emissions because reductions in other sectors will not be enough. Yet with current technologies agriculture can only achieve 20–40% of the reductions needed. This is a massive adaptation challenge and a massive mitigation challenge.

In the areas of the world that we (CCAFS) work, we have undertaken household surveys of 1000s of individuals (Figure 3). Farmers have been classified as stepping up (they're intensifying); stepping out (they're doing something new including growing assets to exit agriculture); hanging in or coping. In the areas where we work, which are perhaps the tougher areas of developing countries, it's only 15% that are stepping up. In some parts of the world, up to 70% of farmers are just coping, living at the poverty level, or below the poverty level. Even worse (last column of the table), up to 30% of farmers are scraping by with many months of deficit.

Figure 4 depicts how climate risk is a key driver of poverty and food insecurity in two different dimensions. Uncertainty is driving lack of both investment and adoption; it will deplete your assets. And in extreme events farmers try to protect their productive assets. For example, in drought in a mixed farming area,

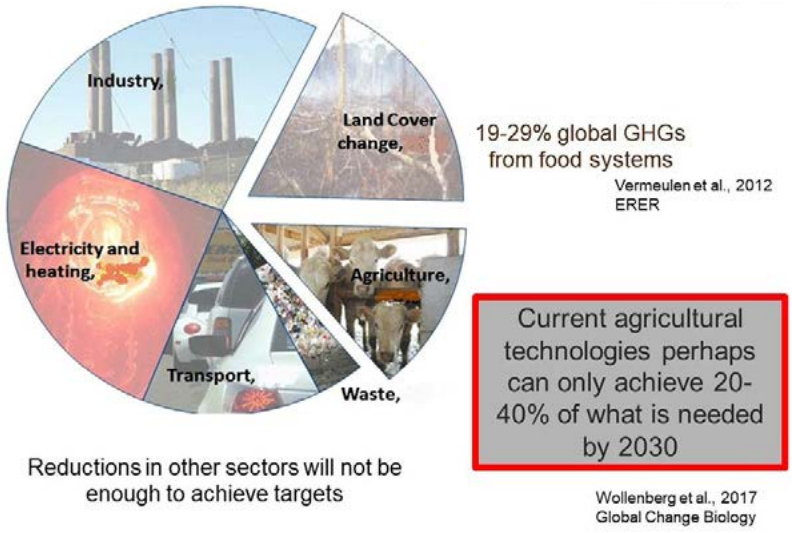

Figure 2. The mega-mitigation challenge. The imperative for food system solutions.

Figure 3. Householders in the poorer areas of the world are taking action.

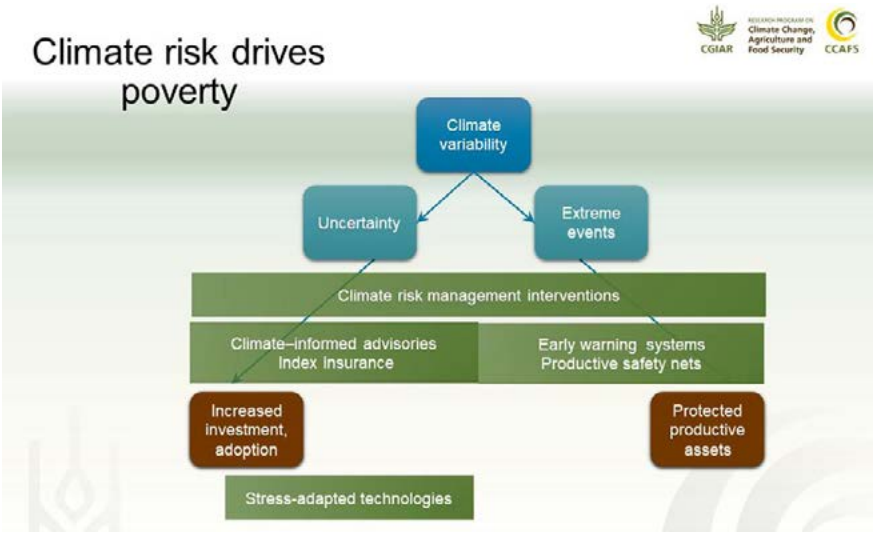

Figure 4. Climate risk drives poverty, through both uncertainty and extreme events.

farmers will sell off their livestock in order to cope with a coming season, though those livestock would otherwise be crucial in the next production system.

Therefore, CCAFS focuses heavily on climate risk management interventions. Farmers get seasonal advisories to know what they can do in the coming season. And there are insurance-type methods available to protect farmers from bad years. There are wonderful things happening in terms of different kinds of climate risk management interventions, to help farmers protect their productive assets. We also have data showing how, if farmers are able to cope with risk, they will also then start adopting stress-adapted technologies.

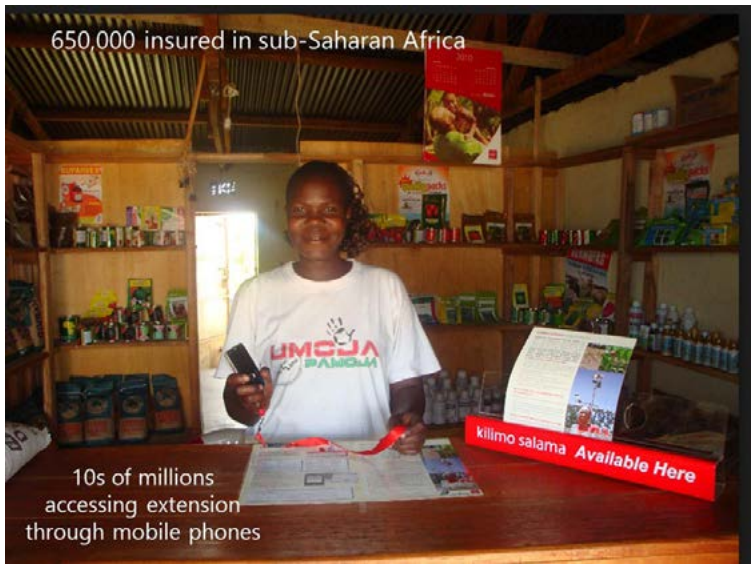

Figure 5. A rural shop in Africa offering banking and insurance services via mobile phones, as well as groceries.

Achievements helping farmers withstand climate change

Here are four examples of the kinds of things that are possible.

There are now more than 100 varieties of *drought-tolerant maize*, available to 2 million smallholders in 13 countries. Also, plant breeders are producing heat-tolerant wheat – something that will be useful to many Australian stakeholders as well. These stress-tolerant cereals are available and being widely adopted, thanks to the work of researchers at CIMMYT, IITA, universities, government and institutions' labs, and private industry.

The development of *mobile banking* has given farmers easy access to drought-insurance products. Farmers in a rural area with a cell phone can take out insurance at the local shop (e.g. Figure 5). They can take a photo of a barcode, apply for the insurance and pay for it immediately via their mobile device. The insurance products are related to climate indexes, and when, say, the rainfall in the local area goes below a certain amount the insured farmers get instantly paid out on their mobile device. Something like 650,000 farmers are insured in sub-Saharan Africa; it's really positive.

Further, tens of millions of farmers now are accessing *agricultural extension services through mobile phones*. It appears mobile devices can lead a revolution.

Third, *climate-informed advisories*. Esoko, which 'provides digital solutions and services for agriculture and data collection, to empower rural populations and the organizations that work with them', working with ICRISAT, has put together

CIMMYT: International Maize and Wheat Improvement Center
IITA: International Institute of Tropical Agriculture
ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

a collection of private and public partners, and after a few seasons of R&D they now have 300,000 smallholder farmers in remote northern Ghana who are willing to pay for climate-informed advisories.

Fourth, a move that really cuts across the energy, water, food nexus. In India, farmers are *selling solar-generated electricity to the grid, and selling water to other farmers*, to acquire more secure irrigation water for themselves. This has positive greenhouse gas implications, when you look at the greenhouse gas emissions from the system, and if you get the incentives correct in their choice between using their solar-generated power to over-pump or selling that extra power to the energy company. The Indian Government has made a USD 21.5 billion investment in this, rolling out 2.75 million solar irrigation pumps.

What about in Africa? Only 5% of cropland in Africa is irrigated at the moment, while the global average is 20%. Can solar power and energy insurance-related models leapfrog the traditional irrigation models?

As well as these great examples, I can think of perhaps another 20 positive initiatives out there. But in fact fewer than 20% of small-scale farmers are stepping up, changing, getting out of poverty – and we have to reach 500 million farming households within a decade if we're serious about achieving the SDGs!

Our theory of change

We are working with multiple partners to try and achieve the changes needed, as outlined in Figure 6. One aspect is technologies, but I think that is under control. Another is finance. Consider the differences between the finance in the world's development communities and the world's investments communities. How can we bring extra public and private sector investment into smallholder farming? And why has it not happened already?

At CCAFS we believe the whole food system is important, and that there is a big opportunity to reshape the way food systems operate. It will involve reshaping supply chains, thinking about food retail marketing and procurement issues, as well as changes to food loss and waste, and to production systems.

We need to empower farmers and community organisations, including women and youth: we have seen some amazing impacts when farmers and local communities can network and change behaviour, enabling them to stand up to the powerful corporate players – to *demand* services.

The last piece of this circle (Figure 6) is digital and, as I have said already, this can really drive a revolution. There is a massive 'connectedness' happening. How

Figure 6. Aspects that need attention to achieve a food system transformation.

can it act as a force of change? Agriculture in the US, for example, is the least digitalised sector of that economy.

And as shown in the centre of Figure 6, the core need to achieve food system transformation is for *policy and institutions to be fostered and engaged*. Therefore, at CCAFS, as a program, we have decided we will not work in places where we do not believe there is serious government commitment to change.

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Dr Bruce Campbell is Program Director of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (www.ccafs.cgiar.org), and a staff member of the International Center for Tropical Agriculture (CIAT). He is based at the University of Copenhagen and Wageningen University & Research. The CCAFS team works on adaptation to increased climatic variability and progressive climate change, and on pro-poor climate change mitigation. The program started in 2010 and has a budget of USD 50–60 million per annum involving all the international agricultural research centres (including forestry, fisheries and livestock) as well as university partners; and operates with staff in more than 20 countries. Bruce has been doing inter-disciplinary science for development for more than two decades, championing new approaches to doing applied research on natural resource management. He was previously based in Zimbabwe, Indonesia and Australia, where he has worked in agricultural and forestry research for development, and indigenous natural resource management. He has published over 150 peer-reviewed articles, more than a dozen books, and writes regular blogs on diverse topics.

Climate-smart villages: key to a sustainable future in rural communities

Professor Alice Joan de la Gente Ferrer*
Division of Social Sciences, University of the Philippines Visayas

Abstract

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) has been pilot-testing climate-smart villages (CSVs) in South East Asia (SEA), in Vietnam, Cambodia, Lao PDR and the Philippines, since 2014. The CSVs serve as loci for community mobilisation and participatory processes, where knowledge and capabilities of men and women are enhanced and their motivation is promoted to take action towards food security, agricultural productivity, and climate change adaptation and mitigation. In the CSVs, evidence is generated at local scales of what Climate Smart Agriculture options work best – where, why and how – and this evidence is used to draw out lessons for agricultural development practitioners, policy makers and investors from local to global levels. The CSV approach, being context-responsive, process-focused and outcome-oriented, strengthens existing village programs and structures towards climate action. The CSV approach is now being considered in programs in the Philippines, Vietnam and Myanmar. Here we report how the CSVs have been contextualised, how participatory processes have been implemented, and how emerging outcomes have been attained.

This paper presents the case of climate-smart villages, part of the CGIAR research program on climate change, agriculture and food security (CCAFS) to scale up climate-smart agriculture. I work with a team (named in the footnote), who are to be credited for the successful run of climate-smart villages in South East Asia for the last five years.

Climate-smart villages are like field laboratories, testing innovative approaches for climate-smart agriculture to improve food, nutrition and income security in the face of climate change. This talk outlines the basic features of the CSVs in South East Asia, the implementation, evidence creation and the scaling mechanisms – and the challenges.

As we know (and Figure 1 reminds us), climate variability is having severe negative impacts on agriculture productions systems. It threatens food and security across the world. There is an urgent need to identify and promote agricultural technologies and practices that provide options for farmers to adapt to current and future climatic variability.

Climate-smart agriculture, CSA, in climate-smart villages

Climate-smart agriculture as defined by FAO (2013) is

> 'an approach for developing actions needed to transform and reorient agricultural systems to effectively support development and ensure food security under climate change'.

This paper has been prepared from a transcript and the illustrative slides of the presentation.
*Professor Ferrer's coauthors are: Julian Gonsalves, Bui Tan Yen, Eisen Bernardo, Nguyen Duc Trung, Bui Le Vinh & Leocadio S. Sebastian.

Figure 1. Climate variability is having severe negative impacts on agriculture productions systems

CSA supports food security in the face of climate change. Its pillars are agricultural productivity, resilience and mitigation. CSA has been introduced in many parts of the world, but there is challengingly weak uptake of many innovative CSA practices and technology.

Cultural production systems are identified as a factor contributing to the low uptake. Therefore, CGIAR via CCAFS has developed the climate-smart village (CSV) approach, with which we generate evidence demonstrating the efficiency of proven and innovative climate-smart solutions; that is, CSA solutions.

The CSV approach is an agricultural research-for-development approach: to test, through participatory methods, technological and institutional options for dealing with climate change in agriculture. It seeks to fill knowledge gaps and stimulates scaling of CSA. It aims (Aggarwal et al. 2018):

> 'to generate evidence at local scales of what CSA options work best, where, why and how, and to use this evidence to draw out lessons for policy makers, agricultural development practitioners and investors, from local to global levels.'

CSVs since 2012

CGIAR, CCAFS started looking at climate-smart villages in 2012 in Africa and south Asia, and in 2014 extended that work to South East Asia and Latin America.

We have seven CSVs in South East Asia (Figure 2): Ma and My Loi and Tra Hat in Vietnam, Guinayangan in the Philippines, Ekxang and Pailom in Laos, and Rohal Suong in Cambodia. They represent diverse climate risks, landforms, cropping systems and land use strategies, and were selected to focus on climate change hotspots and mitigating greenhouse gas from rice production systems.

The CSV approach aims to generate a climate-smart landscape (Figure 3). We involve the local communities and surrounding natural resources in participatory practices. The social mobilisation of CSV starts with building trust through

Figure 2. Climate-smart villages in South East Asia.

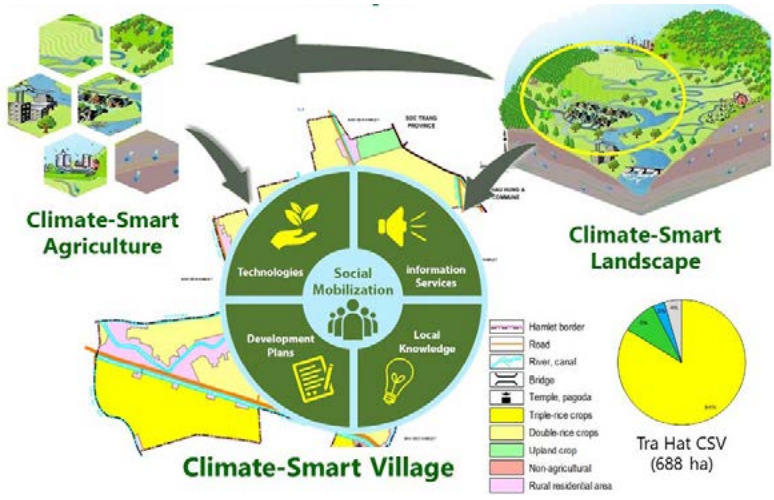

Figure 3. From climate-smart agriculture to a climate-smart landscape.

community engagement and partnership among diverse stakeholders, resulting in the agreement to organise the CSV.

In South East Asia, to set up the CSVs, CCAFS began by working with local organisations, and making baseline surveys to assess the climatic risks and vulnerabilities to agriculture at the household, village and landscape levels, among other things. Participatory land-use planning has become a platform for multi-stakeholder participation and collaborative work in these CSVs.

Context matters!

There is no fixed package of CSA interventions. Figure 4 shows the types of CSA interventions that have been implemented in three CSV sites, in Vietnam, Laos and Cambodia. Options differ based on the sites' agro-ecological situation, level of development, and the capacity and interest of farmers and of the local

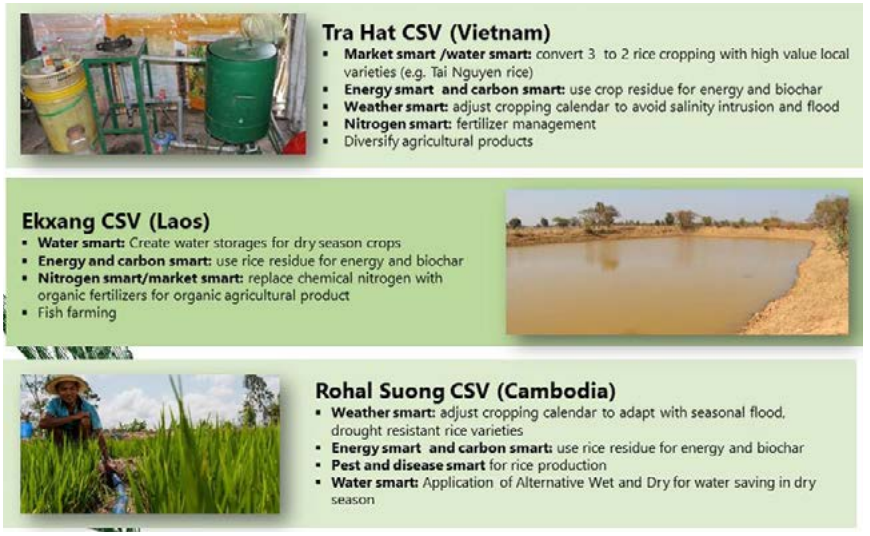

Figure 4. Context matters. Different regions need different approaches. Examples of climate-smart options in CSVs in South East Asia.

Figure 5.

community. Only locally suited and context-specific practices and technologies are implemented and disseminated.

Figure 5 shows the various CSA technologies and practices tested and evaluated in CSVs in South East Asia, using the local context and building evidence that then strengthens the people's capacity to adapt to the changing climate.

We are also scaling CSA up and out, to bring adjusted climate-smart options to larger areas: 'scaling out' via roving workshops (see Figure 6) in the CSVs.

Involving policy and institutions in using the CSV approach

We also are engaged in vertical scaling – 'scaling up' – through policies and institutions (Figure 7). For example, the CCAFS CSV approach is now being

Figure 6.

considered for strengthening climate-smartness of rural communes under Vietnam's National Target Program on New Rural Area (NTM) of the Ministry of Agriculture and Rural Development. In the Philippines, the CSV approach is used by the Department of Agriculture in its 'Adaptation and Mitigation in Agriculture' (AMIA) Project as a template for the AMIA village in 10 regions in the country. In Myanmar, a climate-smart village approach has also been introduced and adapted as part of the Climate-Smart Agriculture Strategy of the Ministry of Agriculture Livestock and Irrigation.

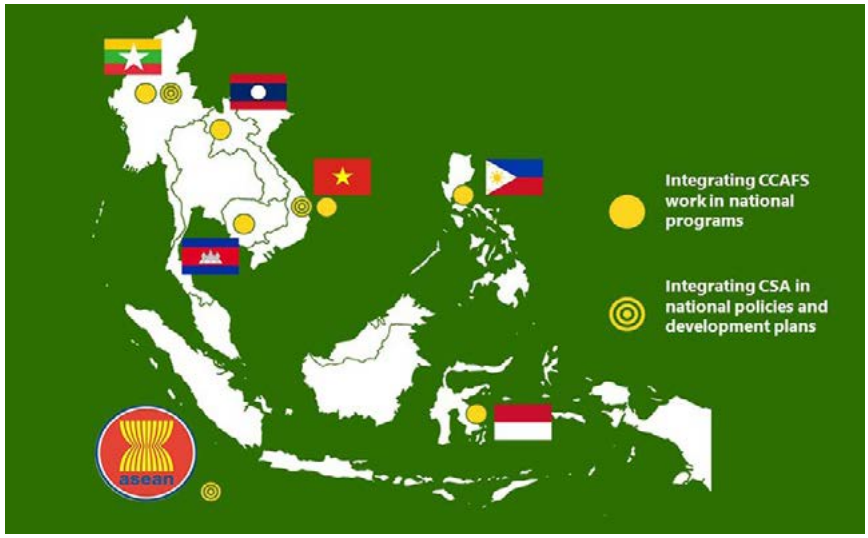

Figure 7. Countries in South East Asia where CCAFS is working.

Figure 8. Eight guide-steps for setting up a climate-smart village.

A CSV scaling workshop in July 2019, sponsored by SEARCA, GIZ and CCAFS, was attended by 12 representatives from seven South East Asian countries.

Summary

In summary, CCAFS climate-smart villages are like field laboratories. Using the eight basic steps in Figure 8, we set up CSVs to test innovative context-appropriate approaches for climate-smart agriculture to improve food, nutrition and income security in the face of climate change.

I would like to emphasise that through CSVs, what we are doing is making villages climate-smart.

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Dr Alice Joan G. Ferrer is a Professor and a Scientist from the University of the Philippines Visayas. She holds a Masters and PhD (Economics) degrees from School of Economics, University of the Philippines. Her interests are in fisheries and aquaculture, social sciences, policy analysis, health economics, gender, climate smart agriculture and governance, among others. She has peer-reviewed journal articles, chapters in books, and a book. Currently, she is the President of the Asian Fisheries Society, National Deputy Director of the Economy and Environment Group Philippines, and the Executive Director of a Health R&D Consortium of the Philippine Council for Health Research and Development.

Raising the steaks: reducing GHG emissions from red meat

Dr Dianne Mayberry
CSIRO and RAID Network

Abstract

The red meat sector makes an important contribution to Australia's economy, but is also a contributor to national greenhouse gas (GHG) emissions. In 2005 (the baseline year for the Paris Agreement), emissions from the Australian red meat industry were 129.3 Mt CO_{2e}; 21% of national emissions. The main sources of emissions were CO_2 from forest land converted to grassland, and enteric methane from grazing beef cattle. Between 2005 and 2016, emissions attributed to the red meat sector decreased by 58% to 54.8 Mt CO_{2e} and 10% of national emissions. This large reduction was primarily due to decreased land clearing for grazing, but there has also been a modest increase in the efficiency of red meat production. Further reductions in GHG emissions from the red meat industry are possible through continued improvements in land management and new options to reduce methane emissions from ruminant livestock. As the custodians of almost half of Australian land, there are also opportunities for grazing livestock industries to be leaders in carbon sequestration. While possible, mitigation and sequestration activities come at a cost, and require investment and policy support from private and government bodies. This needs to be supported by a willingness of consumers, both in Australia and export markets, to pay a higher price for low-carbon products. This case study gives an update to our 2019 paper on carbon neutral pathways, and highlights some of the lessons from Australia that can be applied to developing countries.

The red meat industry is important to Australia and to developing countries. It supports the livelihoods of farming families, and is often the only economic land use in marginal areas where raising crops, pigs or poultry is not possible or profitable. In many systems ruminants also help farmers to mitigate risk by diversifying their sources of income and providing flexibility in their response to economic and environmental conditions.

Australia is one of the biggest producers and consumers of red meat in the world, and around 70% of what we produce is exported to other countries. Locally, the industry employs around 200,000 people and is worth AUD 16 billion. It is also the biggest land use in Australia, with most of our 24 million beef cattle and 71 million sheep raised in extensive grazing systems.

In developing countries, red meat production is a source of income for millions of smallholder farming families. Here, cattle, sheep and goats are used to provide draught power, transport, social status, savings, fibre, fertiliser (manure) and/or milk as well as meat. Red meat production in developing countries

This paper has been prepared from a transcript and the illustrative slides of the presentation.

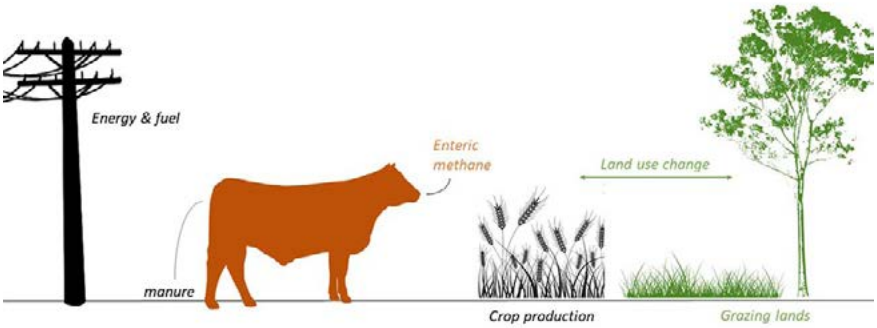


Figure 1. Sources of GHGs during red meat production.

ranges from intensive cut-and-carry systems with small numbers of animals, to extensive grazing of common lands. Productivity in these systems tends to be low, with poor rates of growth and reproduction, and high animal losses.

Worldwide, the red meat industry is facing many challenges, including pressure to minimise its contribution to greenhouse gas (GHG) emissions. To understand how to reduce greenhouse gas emissions from red meat production systems both in Australia and elsewhere, we need to understand the emission sources.

Understanding GHG emissions in red meat production

Greenhouse gases in red meat production come from livestock, crop and grazing land used to produce feed for livestock, and energy and fuel used for transport, machinery and processing (Figure 1). In Australia, the main sources of emissions are livestock and land use change (orange and green in Figure 1). Animal sources of emissions include methane from digestion of feed in the rumen, and animal waste (manure and urine). Enteric methane is the main source of emissions from animals, and the amount of methane produced is directly related to the quality of their diet: animals fed poor quality diets have larger emissions of methane. Emissions from land come from crop and pasture production (e.g. application of fertiliser, decomposition of plant residues, cultivation of soil), and changes to land use and vegetation (e.g. conversion of forest to grazing land).

In a study our team did for Meat and Livestock Australia, we quantified greenhouse gas emissions from the farm, feedlot and meat processing sectors for beef, sheep meat and goats, using data from the Australian National Greenhouse Gas Inventory (Mayberry et al. 2019). As Figure 2 shows, emissions from red meat production in Australia have decreased from 129 million tonnes of CO_2 equivalents (CO_{2e}) in 2005, which is the baseline year for the Paris Agreement, to 55 million tonnes CO_{2e} in 2016: a decrease from 21% to 10% of Australia's total GHG emissions, as CO_2 equivalents.

As a comparison, during the same period, emissions from the energy sector have increased from 65% to 81% of national net emissions.

The red meat industry has committed to further reductions in greenhouse gas emissions and this will rely on methods for reducing enteric methane, especially from grazing cattle, and continued improvements to land management.

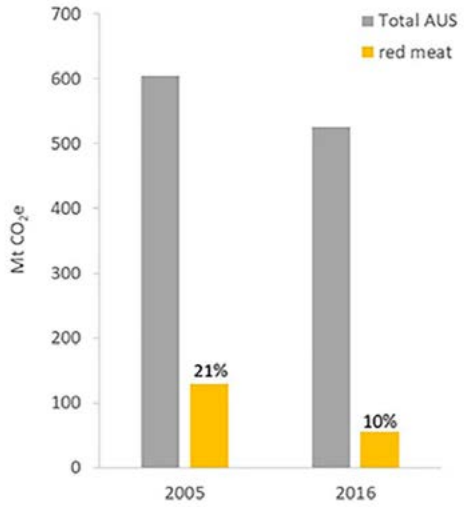


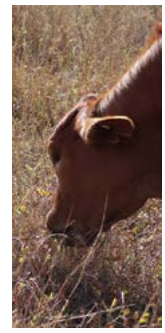
Figure 2. GHG emissions from the Australian red meat industry have decreased since 2005.

Reducing enteric methane

There are several ways to reduce methane production from ruminants, including via feed, vaccines, breeding and animal management.

Feed supplements or additives that reduce the production of methane in the animals' rumens are some of the most promising options. Supplements are perfect for intensive animal production systems such as feedlots, where managers have close control over what and when animals consume. However, most livestock in Australia are extensively managed in pastures or rangelands, and providing a daily feed additive is tricky!

Some current research suggests that tropical legumes, such as *Desmanthus* species, can also reduce enteric methane production from ruminants (Suybeng et al. 2019). Methane-reducing pastures are a much more practical option for graziers. This is important because even if reductions in methane production are not as large as those achieved by some of the feed additives, the method is applicable to a much larger proportion of the national livestock population.



Other options include vaccines that reduce methane production, and genetic selection of animals that naturally emit less rumen methane. While these options are still a long-term goal, especially compared to some of the feed additives, their wide applicability to livestock industries makes them an important part of pathways to reduce emissions.

Finally, methane emissions can also be reduced by improving the productivity of cattle and small ruminants so that we can produce more red meat from less livestock. This method is particularly important for developing countries, where reducing

animal losses and increasing rates of growth and reproduction are currently the goals of many ACIAR-funded projects.

Reducing emissions via land management

GHG emissions can also be reduced through changes in land management. The most important changes to land management are to reduce deforestation and to apply vegetation management that promotes carbon sequestration. These changes can start now. Recent reports have estimated that 58 Mha in Australia would be suitable for revegetation, much of which overlaps with current grazing areas (Bastin et al. 2019). This does not necessarily mean removing livestock from these areas, and increases in vegetation cover may provide some benefits to livestock – such as shade. Vegetation changes could be incentivised by payments for benefits such as carbon sequestration and biodiversity.

Conclusion

The latest IPCC report highlights the need for support from policy, government, markets and institutions to enable change in livestock industries. The red meat production industry requires consistent policies from our leaders, and consumers may need to be prepared to pay more for low carbon products. We also need to remember the multiple benefits of livestock, particularly in developing countries where livestock are kept for multiple purposes.

Finally, the red meat industry gets a lot of press about its contributions to greenhouse gas emissions, but it is not the biggest or only source of GHG emissions in Australia. Reducing emissions from red meat and other agricultural industries is part of the solution, but needs to be accompanied by change in other sectors.

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Di Mayberry is a senior research scientist with CSIRO Agriculture and Food, a founding member and former Vice-President of the RAID network, and a former Crawford Fund conference scholar. Di combines her background in ruminant nutrition (sheep and cattle) with systems modelling approaches to improve the long-term viability of livestock production systems in Australia and developing countries. This includes the use of science to better understand and reduce the impacts of animal agriculture on the environment. Her research portfolio encompasses work at the animal, farm/household and regional scales, and she has worked on sheep, beef and dairy production systems in Australia, Indonesia, China, Myanmar, India and Tanzania.

Q&A

Chair: Mario Herrero

Panel: Bruce Campbell, Alice Joan de la Gente Ferrer, Di Mayberry

Q: Lisa Cornish, Devex
Bruce, I have a question for you. I just want you to expand upon where you said you won't work where there's no serious government commitment to change. Are there governments that you've already said you're not working with? And how are you assessing their commitment to change?

A: Bruce Campbell
I don't think it would be politically wise for me to mention where we won't work, in this audience, and where we decide to stop working as well. It's not simple, but there are various indices out there which one can use, but of course they're not foolproof either. There's governance indices; there's ease of doing business indices;... . Discussions are held in confidence.

Q: Josie Ginty, The University of Melbourne
I was wondering, in the context of the CSVs, as part of the integrated improvement in their agricultural outputs, as a general question to the panel in relation to the role of red meat in diets, what do you think of the potential of fish farming as an alternative source of 'meat'? What do you think the impact of that is on sustainable agriculture?

A: Alice Joan de la Gente Ferrer
What I understand is that in one or two of the CSVs, fish farming is practised but really for home consumption only. However, they're trying to increase production also for market.

Q: Glenn Denning, Columbia University
Climate-smart agriculture claims to have objectives of food security. It's relatively easy to comprehend farmers adopting technologies related to food security, productivity and adaptation; there are clear incentives to individuals to act. I'm wondering if you can give me some examples of how you tackle the third objective, the mitigation objective when there are no incentives?

A: Bruce Campbell
In the conversation with farmers we don't start with climate-smart agriculture. We actually start the discussion with talking about what they want to do in terms of livelihoods. So although it's a kind of guiding principle at the top level, when we're at the field it's what can be done in smallholder dairy, for example, in Kenya. Mario could actually answer the question much better than I could. We talk about practices where there are definite benefits for income, for women farmers, for greenhouse gas efficiencies and adaptation, so they don't see that it's absolutely essential to do all three things in every single place in the world. We use it as a guiding principle in trying to put agriculture on a low emissions pathway.

This Q&A report has been prepared from a transcript.

A: Alice Joan de la Gente Ferrer
The CSA interventions in the CSVs are not fixed. There is a process of CSA prioritisation, based on inputs from multiple stakeholders. You will notice that the CSA interventions adopted in different CSVs differ a lot because of many factors.

Q: John Dixon
For Alice Joan de la Gente Ferrer, thank you for the presentation. One of the key concerns for many of us is about moving to scale. Specifically, from the climate-smart villages, I would like to know what are your key indicators, given the context-specific nature of most of your work?

A: Alice Joan de la Gente Ferrer
There are two mechanisms here. We have the scaling up, where you go to policies and institutions. And then we have to differentiate two kinds of CSVs. One is CCAFS-facilitated CSVs; there are seven of these in South East Asia. And we also have CCAFS-partner-initiated CSVs, and there are many of those. Also, we have the Philippines Department of Agriculture 'Adaptation and mitigation initiatives in agriculture' programs, in my country. Also in Vietnam right now there are only three CSVs, in the north, middle and south of Vietnam, but they are introducing also the concept into the new program in Vietnam, the Nong Thon Moi (NTM) Program.

A: Bruce Campbell
John, Esoko started in a CSV, but essentially they're taking it to scale. So it's thinking about the things we do at R&D platform, and then there are different pathways to scale for different kinds of things: insurance, or technologies, etc.

Q: Peter Wynn, Charles Sturt University
A question for Dr Mayberry. How effective are your dietary additives and your legume in ruminants? And do you think they're going to be applicable for smallholders?

A: Dianne Mayberry
Thanks Peter. The effectiveness of these supplements and additives vary. Some of the algae and seaweed additives have been shown to almost completely suppress methane. Other trials have produced more conservative estimates of a 30–40% reduction in methane, but that's still huge. The same with 3-NOP, which is the additive that DSM are hoping to bring on the market next year. They're saying a 30% reduction in enteric methane. See https://www.dsm.com/corporate/solutions/climate-energy/minimizing-methane-from-cattle.html.

In terms of applicability to smallholder farmers, obviously it's going to come to down to cost and practicability. At the moment some algae is being grown in Vietnam, because it's cheaper than growing it in the US, so if there were places in Asia where you could grow or produce these supplements at low cost, who knows? Maybe it is possible to get them at low enough cost for smallholders, or maybe the governments will support this. If it's supported in the right way, it is possible. And certainly in those intensive systems, if it is economic, it's very easy for farmers to give that to their cattle or their sheep every day.

Q: Luke, The University of Queensland
Continuing off that question there, do you think we should be looking at changing the actual animal systems to possibly other animals that don't produce as much methane?

A: Dianne Mayberry
That's a great question. It would depend hugely on the context. Red meat is produced by ruminants, and the great thing about ruminants is that you can keep them in areas where you can't grow other livestock (like pigs and poultry, which don't produce enteric methane). Where grains are expensive, such as in Australia at the moment with the drought, purchasing feed gets very expensive very quickly and we're seeing pig farmers going out of business because they can't afford feed for the animals. That's not to say the ruminant industries are having an easy time, but sheep and goats and cattle can consume a wider variety of feed including grasses, hay and crop stubbles, which is where ruminants have a big advantage. However, in areas where grains are cheap and readily available, (e.g. South East Asia) pigs and poultry can be a lot more efficient to produce.

Q: Tony
Two questions for Dr Mayberry, who gave an excellent presentation. Can we copy the cobalt bullet technology for supplying these supplements? That's what we used in southern Australia to supply cobalt on a permanent basis to grazing ruminants. And second question is, as we increase woody vegetation, will that mean lower stocking rates and lower profitability?

A: Dianne Mayberry
On the first question, slow release devices or controlled release of compounds to reduce enteric methane in ruminants: yes, I believe that slow-release devices are one of the options scientists are looking at to provide these compounds to grazing animals.

On the second question, have a look at the Wambiana grazing trial over the last two decades, done by Peter O'Reagain and colleagues from the Queensland Department of Agriculture and Fisheries. They've been grazing cattle and they've found that the lower stocking rates have been a lot more profitable than heavy stocking rates, and have maintained pasture condition. So there are ways that farmers can make more money out of these systems.

Q: Female
My question's also for Di. Has there been any research done through CSIRO on the positive effects of hooved animals on pastures and grasslands in the context of carbon sequestration and therefore reducing greenhouse gases? I'm thinking of systems like cell grazing, time-controlled grazing and using hooved animals to actually sequester carbon. We're not hearing this story and about the enormous benefits that the beef industry can bring to that process.

A: Dianne Mayberry
That's a great question. The scientific evidence on this is mixed, and I would point people towards the '*Grazed and confused*' report, published by the Food Climate Research Network in 2017, for a summary of these issues. I think it will

depend a lot on the places where these systems are in use and how livestock are managed. Factors that limit carbon sequestration include extremes in temperatures, fire, floods, drought: those relate to a huge amount of northern Australia. But in southern Australia where we have different climates and different pasture species, there may be opportunities for sequestration. I can't answer your question better, though I'm sure there are people here that can.

Q: Mario Herrero
Bruce, you showed some very modest numbers for farmers 'stepping-up', intensifying – farmers really making significant improvements. What does that say in relation to programs like CCAFS that are funded externally and that have huge expectations of creating change in these smallholder communities? Are there things that you would have done differently if you had known those results in advance?

A: Bruce Campbell
Those numbers were from the start of our work, so the hope is that there's massive change. In the last 18 months we've been on, development assistance in its current shape is not going to deliver the goods, and that last circular diagram that I put up, essentially shows that we really need to do something differently. And that means us not being researchers trying to get partners to do our things, but being researchers that are responsible as part of a partnership in development. And I could just say that I've seen the new figures for Ghana, northern Ghana, where there's some massive take up of the work that we've been doing, so there are some positive stories as well.

Chair: Mario Herrero
That's a great way to finish a session like this one. So it seems that there is a perfect storm brewing for creating positive change, and that's great.
Please, let's thank the speakers for some great presentations.

Crops, drops and climate challenge: using energy efficiency to configure the perfect sustainability storm

Dr Ajay Mathur
The Energy and Resources Institute, New Delhi

Abstract

Water availability, at the right time and in appropriate quantity is at the heart of agricultural practices worldwide; and the availability of water is largely dependent on the use of energy to pump it. Energy use also drives many other farm operations – tilling, sowing, harvesting and the manufacture of chemical fertilisers. We have, over the years, tended to overuse both water and energy in agricultural operations; practices that are now at odds with the challenges due to the emerging changes in hydrology and the increasing global concentration of greenhouse gases (GHGs). It has been argued that water-use efficiency and energy efficiency in agriculture are self-regulating phenomena, largely driven by water and energy prices. This is only partially correct now. Climate change requires us to effectively decarbonise our economies by the third quarter of this century. This implies that agricultural operations will need to become fossil-fuel free in the next two decades. We believe that this requires three parallel interventions: (i) enhance water-use efficiency and energy-use efficiency in agricultural operations; (ii) convert agricultural operations to use electricity instead of fossil fuels; and (iii) decarbonise the electricity supply by converting to renewable sources, instead of fossil fuels, as energy sources for electricity generation.

All the three interventions require policies, incentives, and regulations for their initial acceptance, commercial model development, and large-scale replication. However, the first two interventions require actions mainly by farmer-entrepreneurs, while the third intervention requires action both by the farmer-entrepreneurs (through generating their own solar electricity) as well as by electricity generation companies. What would these interventions look like? An example that covers all the three interventions is the promotion of energy-efficient solar pumps for irrigation accompanied by micro-irrigation facilities, with the excess electricity being bought by the electricity distribution company. The micro-irrigation facilities and the energy-efficient pump reduce the requirement for water pumping, and consequently the electricity needed to pump it, thus reducing the cost of the expensive solar panels. At the same time, the purchase, by others, of the excess electricity provides a revenue stream for farmer-entrepreneurs, which enables them to invest in the solar panels, energy-efficient pump and micro-irrigation facilities, as well as minimise fertiliser and water use. Another example is the promotion of energy-efficient electric tillers, harvesters and other farm equipment. These avoid greenhouse gas emissions, at the user level, and provide the potential to contribute to zero-GHG agriculture with the decarbonisation of the electricity grid.

This paper has been prepared from a transcript and the illustrative slides of the presentation.

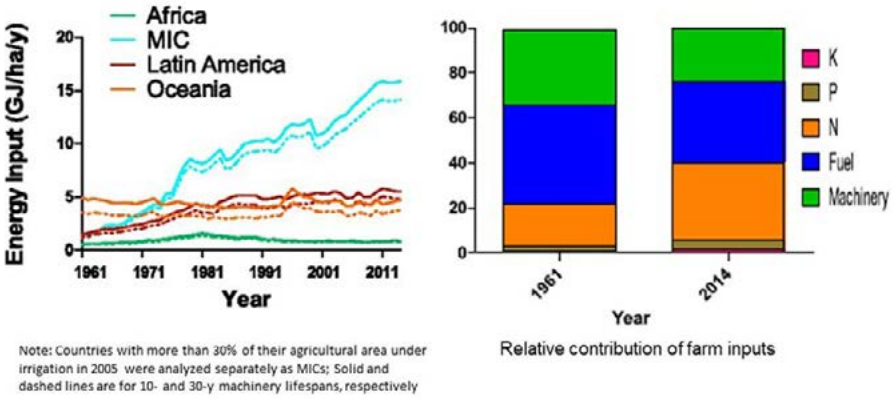

Figure 1. Yields have increased as have fertliser-use and water-use.
Source: Pedro Pellegrini & Roberto J. Fernandez 2018.

> Energy-efficient solar pumps with micro-irrigation facilities are already less expensive, on a lifetime cost basis, as compared to flood irrigation by inefficient diesel or electric pumps. Similarly, electric machinery is cheaper than diesel-run machinery, though the capital cost is higher for electricity-driven machinery, such as electric tractors which require onboard storage of electricity in batteries. The major challenge that these interventions face is the creation of demand for the zero-GHG energy-efficient options (so that economies of scale can drive down prices); and the availability of capital (loans) for farmer-entrepreneurs to invest in these options. These are challenges that have been successfully overcome in the past – in enabling the Green Revolution, and more recently in building the market demand for energy-efficient refrigerators and air conditioners, buildings, etc. Drops for crops are essential; energy efficiency provides us with the entry point to enable a perfect storm for change – which addresses the wellbeing of the farmer-entrepreneurs and local water availability, as well as global climate concerns.

This paper is about ways of enhancing energy efficiency and the use of renewables in agriculture, as a key entry point to ensuring that we are able to stave off the third Malthusian doom. Energy efficiency, as can be expected, enhances productivity and therefore enhances profits. By using energy efficiently, the farmer can achieve much better managed water use, with lower carbon dioxide emissions at the same time.

The water challenge in farming

As a result of the Green Revolution, yields have increased, but at the same time we have increased water use (Figure 1). Windows for irrigation at critical growth stages in all crops – for example, rice and wheat – are small (Figure 2), and therefore farmers have tended to over-irrigate to ensure enough hydration at those critical stages. If the plant cannot access enough water at those times, you have a crop failure. Where the water source for irrigation is groundwater, we see over-extraction of groundwater. As a result, the groundwater level falls and more energy is needed to pump it up, to guarantee crop production.

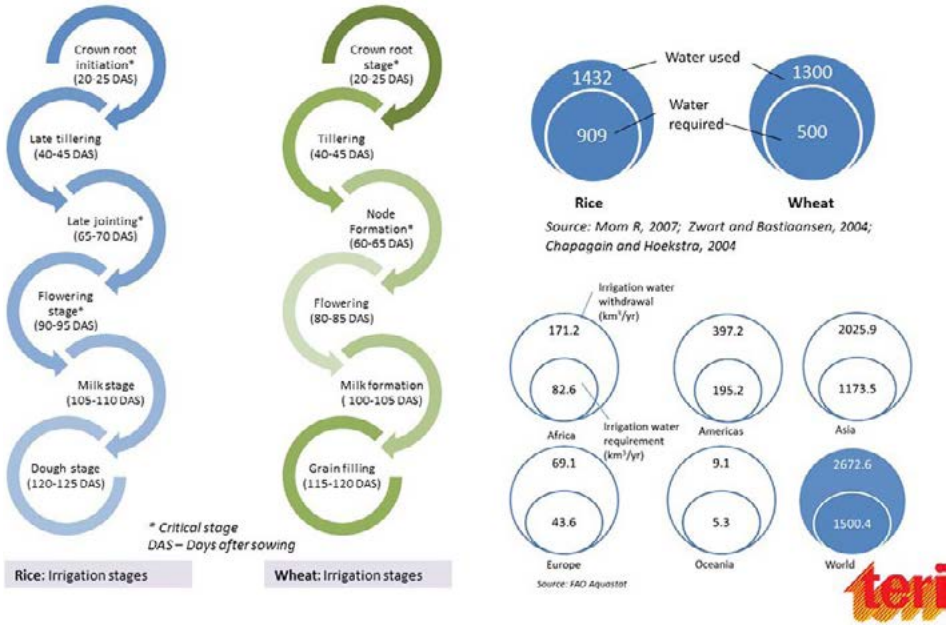

Figure 2. Windows for irrigation are small.
We have tended to over-compensate and over-irrigate.

With climate change, we already experience greater volatility and unpredictability of weather, affecting agricultural productivity (Figure 3). The latest statistical analysis of monsoons indicates that while the total amount of water available available from the monsoon has not decreased, the number of rainy days has dropped, and there are periods of drought in between. This tests the ability of farmers to have the soil wet at the times when they need it.

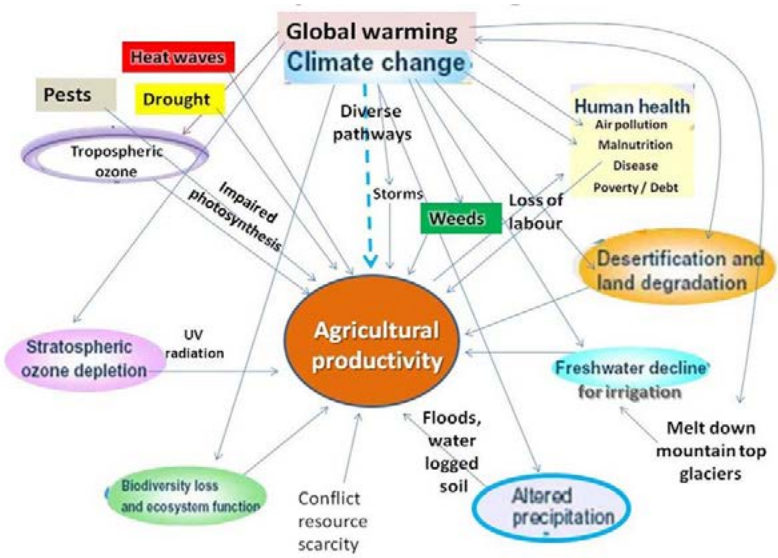

Figure 3. Multiple impacts of global warming and climate disruption on agriculture.

Improving the efficiency of energy use

Instead of the natural tendency to over-compensate and over-irrigate, I would strongly argue that we need to ensure that water use efficiency is maximised.

One of my roles is Chair of the Global Energy Transitions Commission, and in that body we have tried to make sense of how countries and companies should address climate change impacts, to help prevent the world warming by 2°C above preindustrial levels. We agreed on a four-stage process, and that the first thing we have to do is reduce the amount of energy that is used: to maximise energy efficiency. Once you have minimised the amount of energy needed for a process, then you can go ahead and decarbonise the electricity sector, using renewable energy technology (Figure 4).

In India, we have been relatively successful in doing that. For example, a kilowatt-hour of electricity from solar generation today costs less than a kilowatt-hour of electricity from coal. Although that is only true when the sun is shining, we are moving in the right direction, and tomorrow or the day after tomorrow when storage batteries are cheaper the equation will change completely. I would argue we are in a process of transition, moving away from fossil fuels, towards renewables and storage, for mainstream electricity supplies.

As part of our analysis (Figure 4) we considered industry. India and similar countries are producing increasing amounts of steel and cement, that need large amounts of energy throughout each 24 hours. Those industries have invested in fossil fuel energy production, because currently renewable energy cannot supply

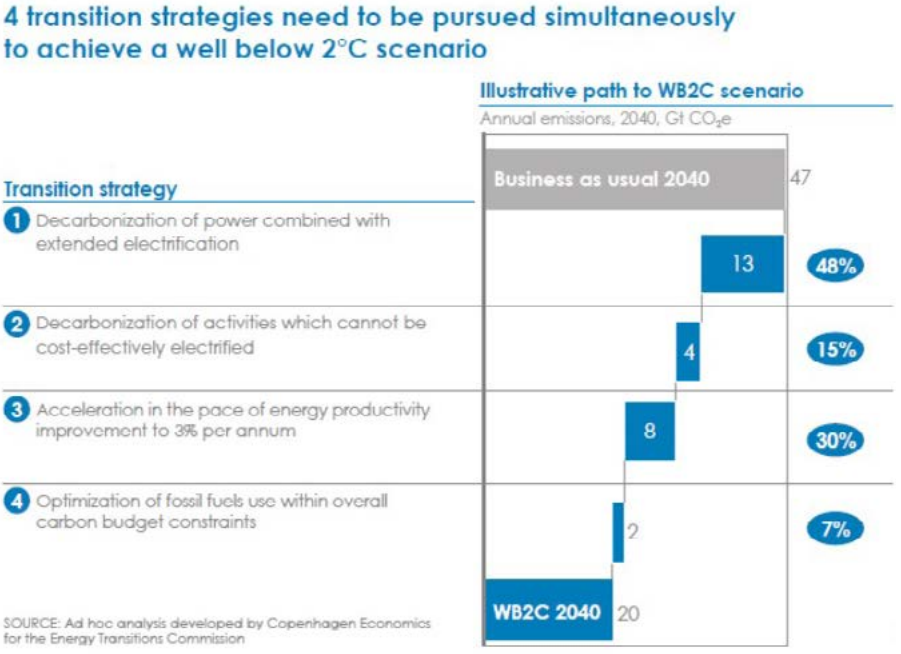

Figure 4. Achieving the Paris goal needs action on several fronts in the agricultural sector. *Source*: Adhoc analysis developed by Copenhagen Economics for the Energy Transitions Commission.

their needs. So, for heavy industry, we need to optimise the use of fossil fuels within India's overall carbon budget constraints by 2040 (Stage 4 in Figure 4).

In the agricultural sector, however, investment in technology development – to decarbonise electricity, and maximise use of electricity instead of fossil fuels – is important if we are to reduce the sector's greenhouse gas emissions.

Decarbonising the agricultural sector

For decarbonising agriculture, we need to enhance water use, and energy use, and fertiliser use efficiency. A move to biological sources of plant nutrition, such as mycorrhizae, and away from manufactured fertilisers, is likely to be part of that; however, we are still learning.

We also need to convert agricultural operations so they use electricity instead of fossil fuels, such as for tilling and sowing, and also to convert electricity generation to renewable sources and away from fossil fuels. Changing over to renewables has a capital cost, but that can be eased by using the right business models, the right kinds of bank loans. It should not require subsidies, but rather a reorientation of how finances flow into this sector.

A large solar pumping program was introduced in India, to encourage farmers to irrigate using electric pumps, at zero or near-zero cost because there were huge subsidies. However, the free electricity led to over-pumping, and over-extraction of groundwater.

The new program that has been launched in March 2019 provides for the solar-pump-generated electricity to be sold to the electricity grid when it is not being used for pumping water. That gives farmers an additional revenue stream (Figure 5). And for the grid managers it is far more attractive to get electricity generated lcoally in a rural region than to get it from a power station far away, with associated losses along the transmission line.

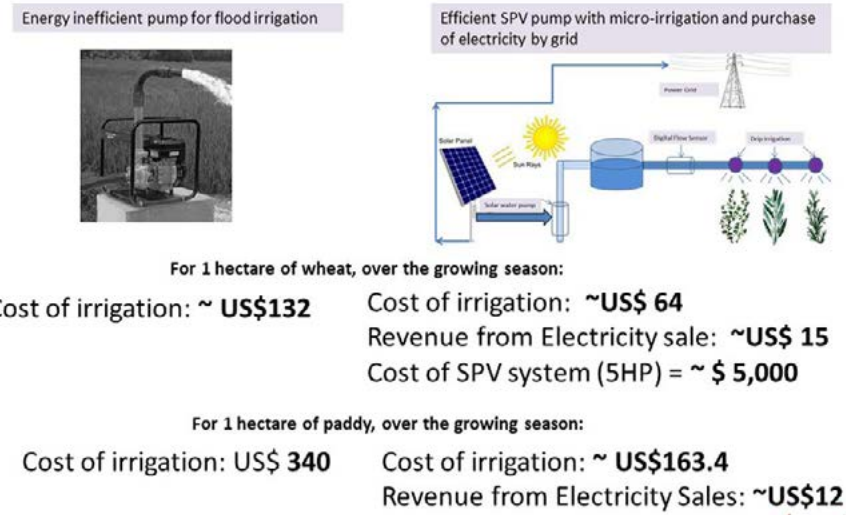

Figure 5. Green farming, and typical costs for water pumping and water use.

Business model. The key to achieving this solution is to have a suitable business model – because farming profitably with one crop is difficult; with one crop and electricity sales, it is easier; and with two crops and electricity sales it is better still. The structuring created for this program enables the farmer to put in a solar pump and pay for it from the electricity he sells to the grid.

Scaling up. We have about 20 million pumps that would need to be changed to solar pumps. In my view, this is clearly the best thing to do. The challenge here is to bring down the cost of solar pumps. Creating demand is the key issue, to achieve economies of scale. Possibly loans for zero-carbon options would be a way of stimulating demand.

These are exactly the kinds of issues that we faced when we were looking at the multiplication of high yield varieties during the Green Revolution. It was exactly the same challenge: how do you scale up a good solution to be taken up widely, and enable price reductions? Public commitment to agricultural production and growth was high during Green Revolution. Similarly, public commitment to clean and resource-efficient technologies (solar pumps, micro-irrigation, etc.) is high now in the agriculture sector, and can be included in broad strategies to promote sustainable food and land use systems.

In summary, success in this energy-efficiency and water-use-efficiency program depends on initial investment and demand creation.

A different example that succeeded

In 2012 a LED bulb in India cost about 500 Indian Rupees. The LED bulb paid for itself, because of its energy efficiency, in three years. But nobody bought it. I didn't buy it. We all understood that price was an issue.

What we did was create a special purpose company, launched in 2015: the Unnat Jyoti by Affordable LEDs for All company (UJALA). That company then made agreements with you and me, through our electricity companies, that they would sell us LED bulbs, with no subsidies, but they would recover the money at 10 Rupees a month, and keep on recovering it until they got all their money back. And they would change the bulb if it failed, no questions asked.

More than 900 million LED bulbs have now been delivered across the country. The UJALA scheme is making an enormous impact by securing annual energy savings, and reducing CO_2 emissions per year and electricity generation (Figure 6). It has completely changed the Indian market.

For our solar pumping program, it is this kind of aggregation on the one side and bulk procurement on the other that we foresee succeeding. The scheme should reduce water extraction, because now the farmer thinks, "Should I extract water? Or should I sell the electricity that is available?". Therefore he is doing a kind of a trade-off. If he does produce more water than he needs, he thinks, "Should I sell it to the farmer next door?".

Thus, in spite of this third wave of Malthusian pessimism, we do have options that help us move towards an optimistic solution.

Figure 6. India's experience with LED bulbs, as it might be applied to solar pumps.

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Dr Ajay Mathur is the Director General of The Energy and Resources Institute (TERI), New Delhi, and a member of the Indian Prime Minister's Council on Climate Change. He earlier headed the Indian Bureau of Energy Efficiency and was responsible for mainstreaming energy efficiency through initiatives such as the Star Labelling program for appliances, the Energy Conservation Building Code, and the Perform, Achieve & Trade program for energy-intensive industries. He was a leading climate change negotiator and was the Indian spokesperson at the Paris climate negotiations. He served as the interim Director of the Green Climate Fund during its foundational period. At TERI, he has spearheaded the move to accelerate action towards a low-carbon and cleaner economy through the adoption of renewable energy in the Indian electricity sector, enhancing efficiency in buildings and industry, and promoting environmental quality through recycling of material wastes and biotechnology-based solutions. He co-chairs the global Energy Transitions Commission, and one of the climate initiatives of the One Planet Summit.

Institutional innovation for energy, food and water security in South Asia: the Sustainable Development Investment Portfolio (SDIP) Programme

Dr Jim Woodhill
Environmental Change Institute, University of Oxford

Abstract

Rising populations, rapid urbanisation, industrial expansion and economic growth are projected to significantly increase the demand for water, energy and food in South Asia over the next two decades. Energy demand alone is projected to more than double by 2040. Water availability per capita is expected to continue its long-term decline, particularly in Pakistan and parts of India where, within 20 years, it could reach crisis levels in some subregions. Arable land per capita will also continue to shrink and increases in food supply will need to come from intensified agricultural production systems and/or increased food imports. Climate change is expected to exacerbate these emerging issues of resource scarcity. Rising temperatures, changes to water resource availability – resulting from melting glaciers and changed precipitation regimes – and increases in the intensity and frequency of extreme weather events (droughts, floods and heat waves) are all projected to adversely impact on economic activity, especially in the agriculture and energy sectors. Maintaining water, energy and food security will be a significant challenge for South Asian countries. Competition for land and water resources is set to intensify, driven by increased demand from agriculture, the energy sector and industry. Emerging resource constraints may involve difficult resource allocation trade-off decisions across sectors. Balancing the competing demands will be essential to sustaining future economic growth, poverty alleviation (especially achieving Sustainable Development Goals) and in maintaining national and regional political security. The extent to which South Asian countries can effectively manage these emerging issues will largely determine the region's future economic development trajectory. Adopting a more integrated 'nexus'-based approach to natural resource management and development planning offers much potential for improved water, energy and food (WEF) security and enhanced climate change resilience. Australia, through the Sustainable Development Investment Portfolio (SDIP), is supporting countries to better manage these emerging WEF security constraints, through targeted aid program investments and public/economic diplomacy. This paper highlights some of the innovative approaches that have been supported through SDIP and how they are contributing to improved development outcomes in the agriculture and energy sectors in South Asia.

I want to share with you some of the experiences of the Sustainable Development Investment Portfolio. First, imagine that you are a female farmer, somewhere in the Eastern Gangetic Plain. You have three children. Their diet has not been great, and they are probably a bit smaller than some other kids

This paper has been prepared from a transcript and the illustrative slides of the presentation.

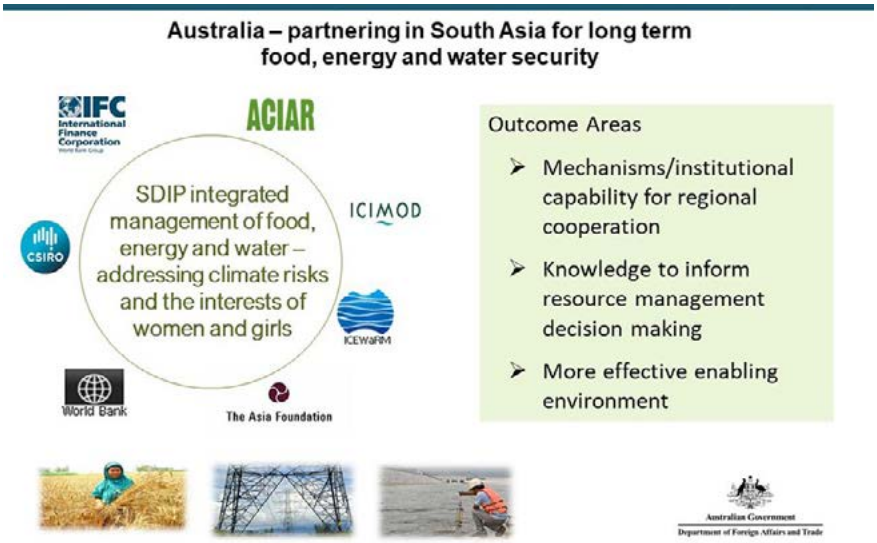


Figure 1. Sustainable Development Investment Portfolio (SDIP)

of a similar age elsewhere. Thinking about how you can pay for their education and their health over the coming few years, you see around you opportunities to produce more. You see solar pumps, you see mobile phones, and agricultural inputs. You know these could help you be more profitable, but to access them will involve a trade-off with the food and education your children need – today.

The reality for tens of millions of farmers and people across that Eastern Gangetic Plain is that water, food and energy are inextricably linked in their day-to-day lives.

What creates incentives for that woman farmer to have opportunities and do something differently? What happens when all of that goes to scale? And how do you ensure that scaling up happens in an equitable way so that the poorest of the poor still can benefit from the opportunities?

Energy, food and water are the resources that we try to tackle in an integrated way through the Sustainable Development Investment Portfolio (SDIP) program. SDIP is a collaboration between the Australian institutions CSIRO, ACIAR and ICE WaRM and others (Figure 1), with linkages to research organisations, and other partners in the region such as the The Asia Foundation, ICIMOD and the World Bank. We are working together around this challenge of how to create long-term institutional mechanisms for tackling water, food-aid, energy nexus issues.

Cross-border issues are very important in relation to water, energy and trade. In SDIP we focus on how to create the capacities, scientific knowledge policies, and institutional mechanisms to improve cross-border collaboration. However, these

ICE Warm: International Centre of Excellence in Water Resources Management
ICIMOD: International Centre for Integrated Mountain Development

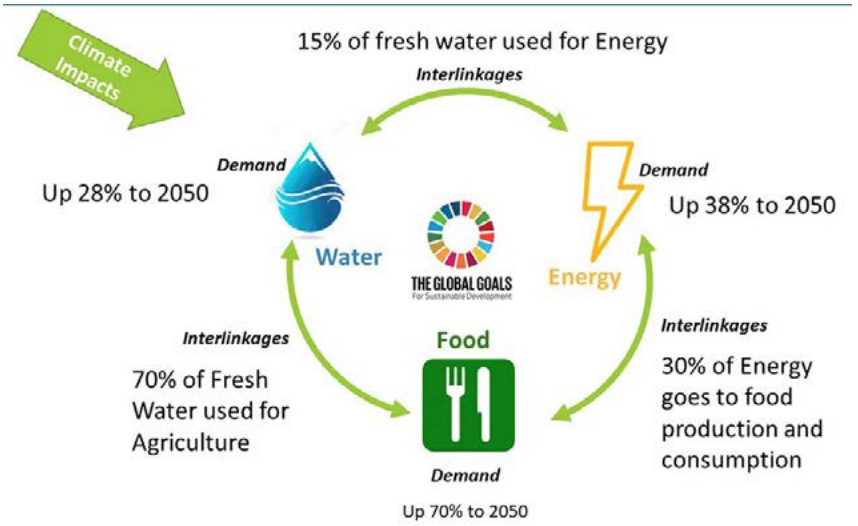


Figure 2. The food, energy and water nexus.

challenges are not solved by short-term technical fixes. I think SDIP is unique because it is not saying, "How can we get a development result tomorrow?". It is saying, "We've got some deep challenges that are going to take long-term thinking, commitment and engagement. We recognise that they are enormous challenges."

I took you to the very local level, imagining you are a woman farmer. Now, take a global perspective for a moment as we start thinking about the nexus. Figure 2 presents a few big figures that predict how demand is going to change over the coming decades. We know that 30% of energy produced goes to agriculture; we know demand for food is going to go up enormously; we know that energy demand is going to go up by about 38%, and water demand is consequently also going to increase.

Already for South Asia, this all just doesn't add up. For South Asia demand is growing faster than in the rest of the world. When we add climate change predictions onto that, we really have to radically rethink how to structure, organise and integrate our use of these three resources in this region. This situation is a 'hot spot' on Australia's doorstep (Figure 3). South Asia's population will soon be 2.2 billion or so, and 15% live in poverty; there is a high proportion of stunting in children; and climate change is potentially going to have massive impacts in that region. Climate change related natural disasters are already experienced on a significant scale, and are likely to become more frequent.

Unfortunately, there are significant institutional constraints to more integrated approaches. People still work in separated areas – 'stove pipes': policy stove pipes; sector stove pipes; government, business, civil society stove pipes (Figure 4). In the SDIP program we are trying to build bridges between these stovepipes. Australia has much expertise in working in more integrated way, and not always successfully.

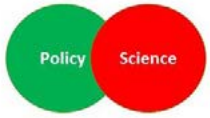
Population – now 1.870b; 2050 2.24b
Poverty – 15%
Under $3.10 – 50-60%
Urbanisation – now 35%; 2050 50%
Stunted Children – 37.5%
Over 90% of water used for agriculture
Climate change – 35-40% decline in crop yield; 10% more irrigation water used

Energy
- Massive growth in demand
- Critical to prosperity of the region and tackling poverty
- Energy choices will have long term Impacts
- Significant agriculture/energy/water linkages
- Climate change impacts on and of energy

Figure 3. The nexus challenges for south Asia.

Policy Stove Pipes
Sector Stove Pipes
Government, Business, Civil society Stove Pipes

Weak Mechanisms for cross boarder resource management



Less than adequate Science Policy Interface

Limited Foresight and Scenario Thinking

Figure 4. Institutional constraints.

Our future thinking (foresight) is often limited. Part of the SDIP work is looking at the long-term implications of changing food systems, and trying to understand the implications of different future scenarios.

We have a less-than adequate science–policy interface in many areas. Figure 5 lists examples of where the SDIP program is having an impact, including: improved energy and water use in agriculture (see Dr Ajay Mathur's paper, p. 55, this Proceedings) through the adoption of conservation agriculture; improving resource use in key industries; improving analysis of resource-use trade-offs; supporting analysis of the Himalayan mountain regions; and helping create new opportunities for dialogue.

- Improved energy and water usage in Agriculture – reduced GHGs and increased yield - adoption of conservation agriculture across EGP
- More energy and water efficient industries – sugar industry in Nepal, garment manufacturing in Bangladesh
- Large scale solar energy in India reduction in water use from 5 to 0.03 ltr per kw/h relative to coal – and 18 million access to off grid small home appliances – reducing dependence on kerosene and biomass
- Co-developed the trial Indus River System Model (IRSM) – Water Apportionment Accord (WAA) tool that can support foresight and trade-off analysis
- Support for the Hindu Kush Himalaya Assessment - categorical assessment that 1.5 degree increase is too hot
- Development of food systems foresight and policy processes
- Spaces for dialogue- cross institutional and cross jurisdictional

Figure 5. Examples of impacts achieved through the SDIP program.

Figure 6 (sideways, next page) outlines thinking about innovation systems to support dialogue. Quantitative models can support more informed dialogue process and improve policy-making. There will also always be a 'Beyond Science' dimension (top left) to decision making. A conference like this is an opportunity to integrate science and dialogue and drive greater synthesis science (middle part of the diagram).

I think it is synthesis work that is needed to tackle many of the issues addressed in this conference. Investment is needed in this space. It is important to gain a much deeper understanding of the institutional mechanisms that underpin a nexus approach to water, energy and food security and to get such institutions established.

I really like the work of Ulrich Beck who says we need to think about shifting from a society that structures its institutions around wealth creation and distribution, to a society that has much better mechanisms for coping with the risks that we are facing.

We need to stay optimistic, and that we can do that by gaining a deeper understanding of both the systemic risks and the transformational opportunities. In looking at the pressures in South Asia, we see plenty of opportunities for doing things very differently. However, to realise these transformational opportunities we must become much smarter in connecting political innovation, institutional innovation and technical innovation.

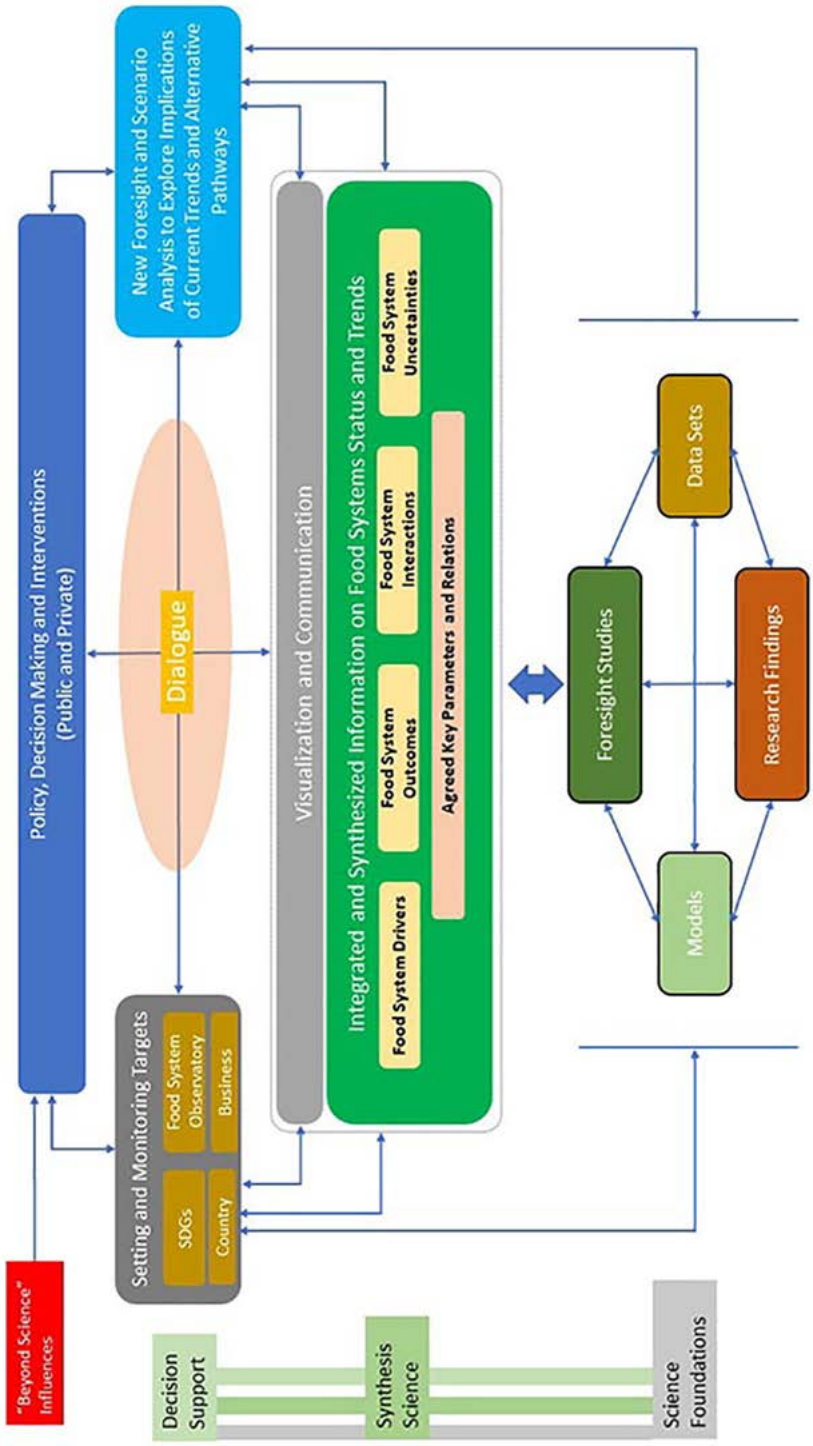


Figure 6. Innovation systems for tackling the nexus.

Dr Jim Woodhill is an Honorary Research Associate with the University of Oxford's Environmental Change Institute and an independent consultant. He is an adviser to the South Asia Sustainable Development Investment Portfolio (SDIP), a program of the Australian Department of Foreign Affairs and Trade (DFAT). Jim is a specialist on inclusive agribusiness, rural development, food security and multi-stakeholder partnerships, with over 25 years of international development experience. Formerly Jim was the Principal Sector Specialist for Food Security and Rural Development with DFAT. Prior to this he was Director of the Centre for Development Innovation at Wageningen University and Research Centre in the Netherlands. He holds a PhD in political economics and a degree in agricultural science.

Finding the best 'ways' with fish passes around dams

Dr Oudom Phonekhampheng
National University of Laos

Abstract

The Lower Mekong Basin provides habitat for more than 480 species and 40 families of fish, many of which are endemic. The catchment provides 2% of the worlds commercial fish catch, with 2.2 million tonnes per annum extracted. Movement of fish through the Basin is vital to maintain fish populations, especially for migratory species. However, thousands of barriers have been installed throughout the Lower Mekong Basin hindering fish passage. Work is being undertaken to establish the best responses to the increasing number of barriers throughout the Lower Mekong Basin. Engineered structures are being designed to account for specific ecological objectives, hydrology and fish species within a site. This endeavour is not without challenges, and one size does not fit all. The Pak Peung Wetland Research site is located about 100 km to the north-east of Vientiane, the capital of Laos. The ACIAR-supported project started in 2008 and a fully commissioned cone fishway was installed in 2014. Monitoring has been an essential part of the project; to learn about the success of the fishway so similar projects can be successfully rolled out across the Basin. This talk discusses an example of an engineered fishway at Pak Peung, Laos, and some of the successes and challenges of fish passage design.

Our project is about how to find the best type of fishway for the Lower Mekong River. Fishways in other countries show they have the potential to solve the problem of how fish can have access upstream and downstream along a river. However, the Mekong offers a number of challenges for fishways, compared to other countries, with the numerous hydropower dams now along its course as the Lancang River in China and Myanmar, and the Mekong River through Laos, Thailand, Cambodia and Vietnam (see map, *left*).

Freshwater fish in the Mekong are very biodiverse: there are more than 480 different species in 40 different families (Figure 1). Only the Amazon Basin has more species of freshwater fish. Many of the species in the Mekong are endemic, and they have commercial value. Annually, 2.2 million tonnes of fish –

This paper has been prepared from a transcript and the illustrative slides of the presentation.

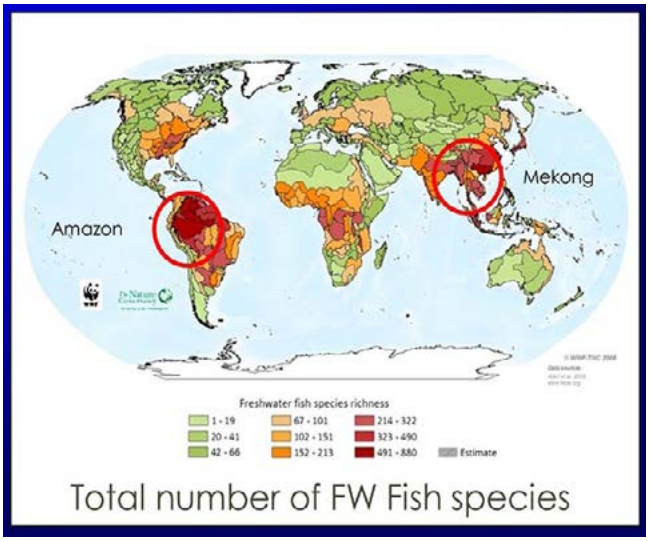


Figure 1. Total numbers of freshwater fish species. The Mekong region (orangey-red) has around 480 species in 40 families.

Source: WWF and The Nature Conservancy, 2008.

2% of the world's total commercial fish catch – are taken from the Mekong. Fish is important to diets here; for example it provides 48% of animal protein intake in Lao PDR and 79% in Cambodia.

The Lower Mekong also has four different agro-ecological zones (Figure 2): the plateau (upland) which is used to grow rice or other vegetables; the lowland areas; the riverine habitats of island-dominated areas such as in Cambodia where there are 4000 islands, and the seasonally flooded wetlands on the floodplain. The livelihoods of people living along the river are based on fishing (Figure 3). The fish themselves depend on being able to migrate between these zones, to areas specific for reproduction, and to maximise genetic diversity and therefore maintain the fish populations.

Figure 2. Four different agro-ecological zones.

Figure 3. Fishing is important for people's food and livelihood.

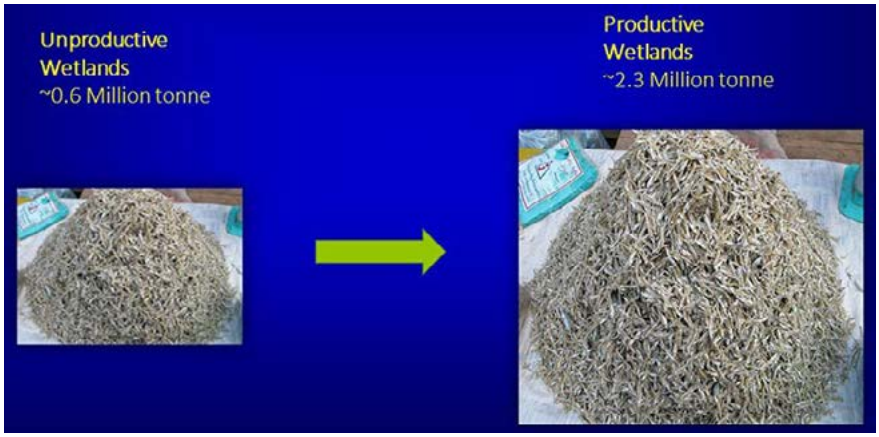


Figure 4. Floodplain wetlands are important feeding and breeding sites for fish, and the richer the resource the more the fish.

Floodplain wetland habitats can be rich sources of food, and important breeding sites (Figure 4), supporting large populations of species vital for human food.

But people have built thousands of barriers (Figures 5, 6, 7) that hinder fish passage and prevent fish migration throughout the Mekong and its tributaries and associated waterbodies. Dams, weirs, levee banks and wetland regulators support the very large irrigation systems that have been established so that rice production could expand, but they restrict fish access to most of the 200,000 km² of wetland areas in the Lower Mekong Basin. The result is that 70% of Mekong fisheries are now endangered.

At Pak Peung village in Paksan District in Lao PDR, after the irrigation system was established about 15 years ago, fish species declined in the area. Fishermen complained that the irrigation water could reach the rice fields, but fish could not, and fish production was suffering.

Figure 5. Types of barriers across the Mekong Basin: planned, commissioned, under construction, cancelled, unknown (see legend). *Source*: CGIAR.

Figure 6. Numbers of dams in the Mekong Basin, October 13, 2016. *Source:* Kim Gehab, CGIAR.

Figure 7. Wetland regulators restrict fish access to the 200,000 km^2 of wetlands in the Lower Mekong Basin.

Source: Marsden et al. 2014

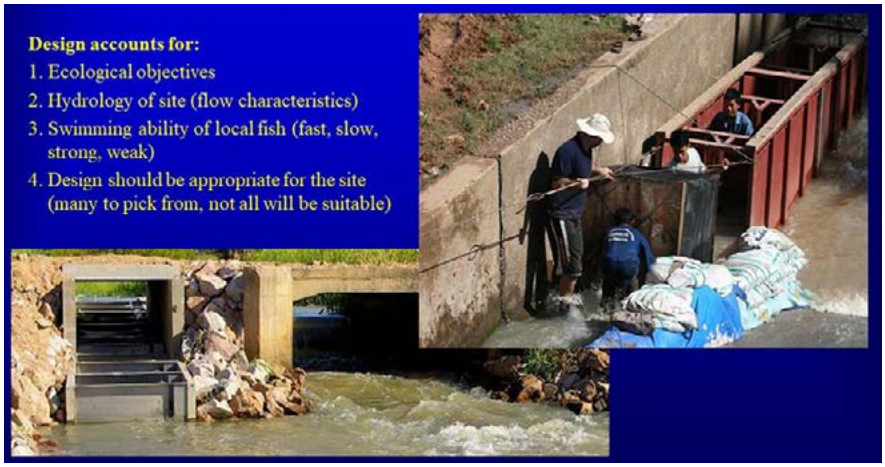


Figure 8. The solution: engineered structures that enable fish to overcome the various physical and flow barriers challenging fish passage.

So, around five years ago we collaborated with Australia's Charles Sturt University to see if we could design a suitable fishway so that fish can swim around the various barriers (Figures 8 – 12).

The project has involved observation and experimentation, and design of permanent fishways appropriate for the types of barriers and the riverine species involved.

Design challenges

1. **Target species**. The Mekong fish populations include a range of species of different shapes and sizes. Some are large, including dolphin and stingray. There are also catfish and many species of smaller size, all with different swimming abilities (Figure 9). It is difficult to design fish passes that function for the whole range of species.

Figure 9.

Figure 10. Some areas experience distinct wet and dry seasons, with large differences in the amount of water present at the same spot in the two seasons.

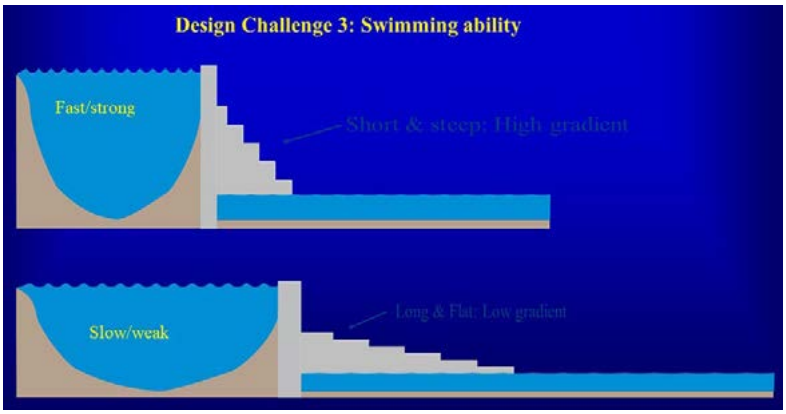


Figure 11. Differing swimming abilities need to be accommodated.

Figure 12. The form of fishway to use is another design challenge: whether a rock ramp fishway (left), a vertical slot fishway (centre) or a cone fishway (right).

2. **Hydrology**. The floodplain is flooded in in the rainy season and dry in the dry season (Figure 10).

3. **Various swimming abilities**. (Figure 11). Fast-flowing water with strong currents tire fish before they can fully negotiate a barrier. For larger fish, shallow

water can be a problem, being difficult to swim in, and not supporting them when they need to jump.

4. **Form.** Rock ramp? Vertical slot? Cone fishway? (Figure 12).

Our trial fishway

We set up our first fishway, or fish ladder, at the Pak Peung Wetland Research Site (Figures 13 and following), beside the Mekong River, and started collecting data on the fish movements upstream and downstream.

From similar work in Australia we learnt, for example, that fish (in both countries) survive passage over overshot weirs better than across undershot weirs (Figure 14), and that led to a new idea: a fish-friendly floodgate to improve survival for undershot weirs. We plan to upgrade existing gates and compare the effects on fish injury and/or mortality.

The project has led to collaboration with Thailand and other countries in the Mekong Basin where fish have been declining, and also overseas. From our

Figures 13 (above), and following. Pak Peung Wetland Research Site

Figure 14. More fish survive overshot weirs (lower diagram & photo) compared to undershot weirs (upper diagram & photo).

experimentation here in Lao, at Pak Peung, we now have an Asian country inviting many other countries to come to see and learn about the problems of fish passage and some appropriate solutions.

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Dr Oudom Phonekampeng is a Laos National who has worked across the globe from Oceania, Australasia, Europe to the Americas. He has over 22 years experience both in teaching and practising animal and agricultural science. He completed his Bachelors in Russia, Masters in Thailand and his Doctorate in Sweden. His expertise is in aquatic ecology and fisheries, working specifically on hydropower and agricultural projects. He previously held the position of Dean of the Faculty of Agriculture for a period of more than ten years, and now holds the position of Vice-President of the National University of Laos.

Q&A

Chair: Lucy Broad

Panel: Ajay Mathur, Jim Woodhill, Oudom Phonekhampheng

Chair: Lucy Broad
Jim, to start with you talked about the importance of institutional innovation and combining that with political, technical in terms of change at scale. I just wondered about the role of women in some of those changes?

A: Jim Woodhill
I think we know in agriculture that economic involvement is empowering a new generation of women, so I think it's just something you can't ignore in the way we think about these very challenging issues. The gender dimension is completely embedded across the whole SDIP program. For all of the SDIP partners it's fundamental. I think you need to understand what's happening in decision-making at household level, at village level, and then go beyond that so that whenever you're engaging, you make sure that you have the strengthening of women's contribution to decision-making fully in mind.

Chair: Lucy Broad
Ajay, with solar pumps, have women played a role in those decisions on farms?

A: Ajay Mathur
Absolutely. One of the things that we have noticed is that women play an extremely important role in water management in farms. Sometimes, electricity coming from the grid for the pumps is supplied at night, while a solar pump ensures that it's during the day. Therefore the ability of a woman to plan her time between various activities becomes important. We think that this will make a change in the way in which women allocate time to productive uses.

Q: Bianca Das, the University of Queensland, CSIRO, RAID network
Thanks – those were really interesting stories. I'm just trying to make connections in terms of economies of scale. Is there a role Australia can play in getting more solar panels to smallholder farmers through recycling our panels?

A: Ajay Mathur
The key challenge today is in terms of the supply chain. The second is in terms of the business model. The two issues that I think are most important are demand creation and the availability of local people who can develop and operate the solar pump and the panel. I think there has been a very strong program between Australia and India on skilling of such people. Most of these solar panels are going to be used by farmers, and they're going to be funded by banks, and all of them will want them to be as cost-effective as possible. Consequently it is the efficiency of the panels which matters. With the amount of solar panels that have been used in India we'll be looking very soon at a disaster in terms of the management of waste from PV panels. I think that's an area in which a lot of collaboration is needed now, because you need those institutional mechanisms in place now for the waste that will be produced tomorrow.

This Q&A report has been prepared from a transcript.

A: Jim Woodhill
We found that with a relatively small investment from the Australian side, we've actually been able to help mobilise a much larger investment that then goes into overcoming some of these sorts of barriers.

Q: Lucy Broad
Is there any question about the investment from the Indian Government – $20 billion or so – continuing? How dependent is the update and the transition to solar on that investment from the government?

A: Ajay Mathur
Most of the money is for the initial demand creation, and the hope is that by the time this money is spent the technology and the price will be such that they will be affordable on their own. So first of all procurement is done on the viability gap between what I'm willing to pay and what cost is met through this Government subsidy. And the working hypothesis is that by the time we run through the program and we run through the money, the prices would be such that people would be willing to buy it on its own.

Q:
Thank you for the awesome presentation. Is it economically difficult and costly to provide after-sales services for the solar panels in rural settings?

A: Ajay Mathur
Absolutely.

Q:
And could this be promoting more waste? How do you think farmers perceive after-sales services for their solar panels?

A: Ajay Mathur
The solar pumps are seen as more expensive and therefore the only way that farmers will buy them is if they are provided as an economic package, which they can afford. And that is why the package is designed so that in a sense it becomes free. And once it's paid off then the electricity sales become revenue to them. What is happening is that initially in the first tenders, I think it's a two-year maintenance is built in, into the initial procurement. And the hope is that by that time there'll be numbers, there will be adequate amount of demand for those services to be offered on their own and in a competitive market.

A: Jim Woodhill
Just a side point to that one. Several of us have spoken this morning about small-scale farmers. I think that in all these issues we have been talking about, in the next decade there will need to be a tremendous transformation of small-scale agriculture to tackle environmental and social issues. We cannot go on talking about a small-scale farmer, meaning all smallholder farmers. There are different scales of small-scale farming. We need to start disaggregating who we are talking about, to try to understand the kinds of incentives that are going to drive farmers to change at the various scales. I think we need to know who are we actually talking about when we talk about small-scale agriculture, and how we might work with the very different groups in different ways to tackle the challenges emerging.

Circular food systems and solutions: addressing the nexus issues in South Asia

Dr Aditi Mukherji
International Water Management Institute

Abstract

The Water–Energy–Food (WEF) nexus concept has emerged as a powerful analytical tool for understanding the complex interactions among different sectors. In this paper, I propose that we now need to move beyond analysis to explore how the WEF nexus can be used to solve real-world water, energy and food issues. I use the example of India's WEF nexus to show how solutions for the water sector, especially the groundwater sector, can often be found in either the energy or the food sector. I also argue that policies that use a nexus thinking framework are more likely to solve interconnected nexus problems. The agriculture, groundwater and electricity sectors in India are bound in an unsustainable nexus of mutual interdependence. Growth in the agriculture sector is often reliant on unsustainable practices in the groundwater and electricity sectors. Likewise, policies and practices in one sector affect outcomes in all three sectors. The institutions undergirding India's WEF nexus were shaped by the imperative to make India food-secure at a time when hunger and starvation seemed imminent. While the Green Revolution led to an expansion in India's food production, the de-metering of the agricultural electricity supply in late 1970s–early 1980s led to a WEF nexus that has become untenable in India today. While many accounts of India's rapid groundwater decline do not differentiate across contexts, my work shows that there is wide variation across states in the functioning and outcomes of the WEF nexus that leads to distinctly different outcomes with respect to sustainable development. In this talk, through three state-level case studies, I will demonstrate that variation in the WEF nexus is caused not only by the physical characteristics of groundwater endowments and rainfall-recharge in each state, but also by variation in both institutional policies and in political exigencies. It follows that policies to improve the sustainability of the WEF nexus must take into account this inter-state variation and that a sustainability solution for one sector might as well lie in other related sectors. I make a call for using the WEF nexus concept for finding solutions to the nexus problem.

Two IPCC reports have come out recently (IPCC 2018, 2019), about the global mean temperature rise. The more recent one (IPCC 2019) shows that in most places we could reach 1.5°C above the preindustrial level, anytime between 2027 and 2045. Already almost 20–40% of global human populations live in regions where temperatures have reached 1.5°C above the global mean in at least one season. This really readable report (among IPCC reports) says that to limit all warming to 1.5°C, CO_2 emissions need to be zero by 2050. To achieve that would require fundamental changes in the way we take every decision – in everyday life and in agriculture, in industry, in everything – and deep emission cuts in all sectors and by all stakeholders.

This paper has been prepared from a transcript and the illustrative slides of the presentation.

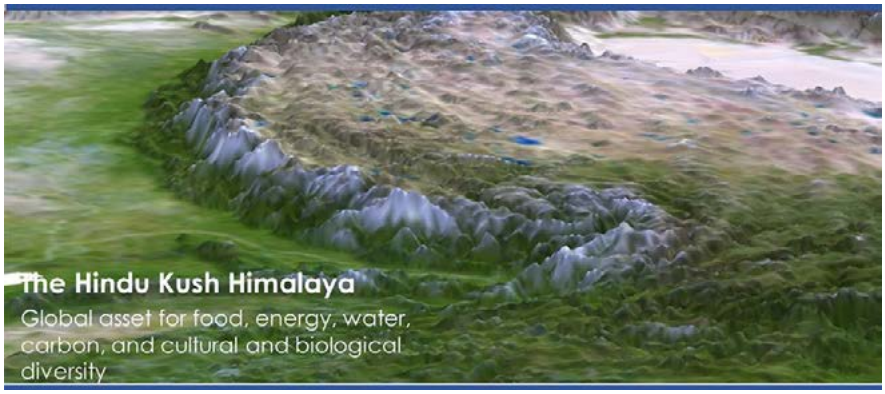

Figure 1.

For South Asia I postulate that current and future risks to water resources result from both climatic and non-climatic drivers. That is, the melting of glaciers, and their impacts on and risks to mountain people and downstream, are attributable to human-induced climate change. However, groundwater over-exploitation and its impacts on agriculture and cities, though exacerbated by climate change, is largely a result of poor policies.

Each now needs different actions: to save our glaciers the global community needs to adhere to their climate pledges; meanwhile, sustainable use of groundwater needs more national and local action.

The Hindu Kush Himalayan region (Figures 1, 2), comprising eight countries, would need to put pressure on the international global community to live up to their climate pledges. In a '1.5 degree' world, Hindu Kush Himalaya would already be losing one third of its glaciers; in a '2 degree' world that becomes 50% of the glaciers. Even 1.5°C is too hot for the Hindu Kush Himalaya because of elevation-dependent warming (Wester et al. 2019; Kraaijenbrink et al. 2017).

What do these changes mean for the region's water resources? Certainly the region would not run out of water. People living close to the glaciers, in Ladakh,

Figure 2.

in Karakoram, who directly depend on glaciers, would be affected. Also, because climate change is expected to increase runoff, at least initially, the downstream flood magnitudes will increase. When I was doing field work in places like Ladakh, farmers often asked us what they can do when their irrigation sources are no longer secure. The sad answer is there is nothing they can do.

Unsustainable groundwater use in India

In India, the Green Revolution looked like a silver bullet. We had millions of people at the risk of imminent hunger and the Green Revolution enabled food production to be increased. But it left behind a legacy of unsustainable groundwater use, unsustainable energy use.

Why such growth in groundwater? Three things: small land-holding, high population density, and the need to grow two to three crops in a year. Groundwater served the purpose, which canal or tank water did not. Not only the area irrigated but also the number of wells and tubewells has increased markedly since 1970. According to the latest survey, there are now around 20.5 million wells and tubewells across India (Figure 3).

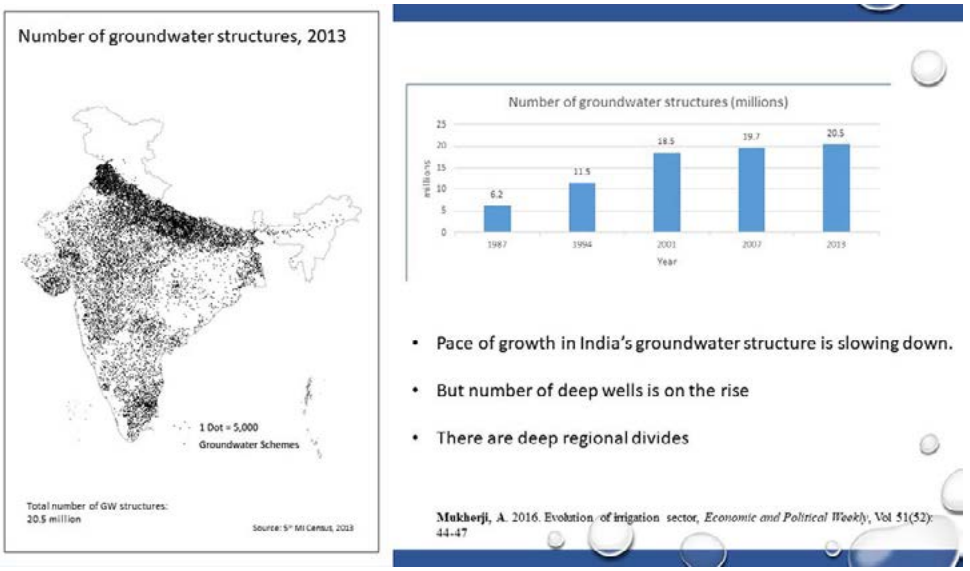

Figure 3.

Groundwater has enabled production of rice, wheat, and dairy. But now there is scarcity of groundwater because of over-extraction – as shown by the red dots on the map in Figure 4 – except in eastern India.

Irrigated rice and wheat are now the biggest consumers of electricity: it is estimated there has been a 12-fold increase in overall electricity demand in India, from 1950, around the time India became independent, to 2010, but a *25-fold increase in electricity consumption in agriculture*. Farmers get free or highly subsidised electricity in most states, and are therefore blamed for the poor financial status of the states' electricity utilities. But farmers also receive very poor quality service.

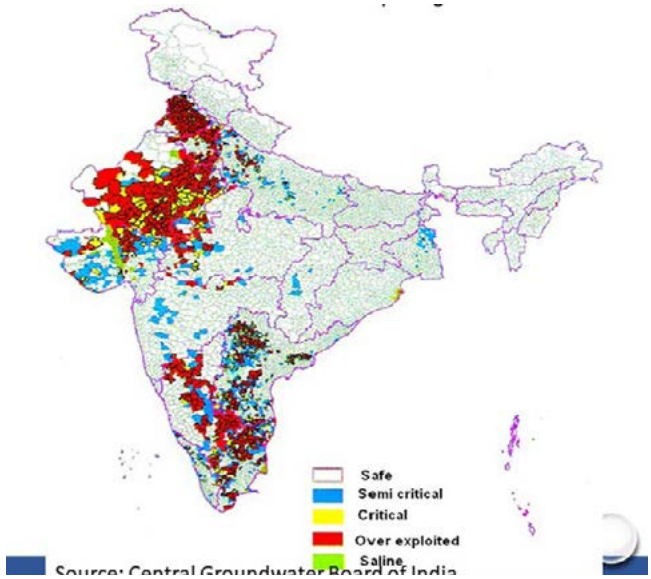

Figure 4. Status of groundwater across India. *Source*: Central Groundwater Board of India.

However, India is a big country. That electricity situation holds true largely for western and northern and southern India, while the entire eastern India depends on diesel pumps.

Some of the work that we have been doing at the International Water Management Institute (IWMI) shows that different groundwater electricity regimes require different solutions: places where groundwater is under-developed can potentially become the future food basket for the nation, with solar-driven irrigation instead of diesel pumps.

Solar irrigation and groundwater sustainability

Promoting grid-connected solar irrigation can help farmers in areas where groundwater has been over-exploited to reduce groundwater pumping, and sell solar electricity back to the grid. This is a win–win solution, reducing groundwater extraction without compromising incomes. In effect, solar power becomes a remunerative 'crop', offering farmers an additional climate-proof income source, and incentivising them to become water and energy efficient.

Selling back to the grid:

- improves the financial viability of power-distribution companies.
- reduces the 'dead-weight' of farm power subsidies.
- generates 'green' energy and contributes to India's renewable energy targets.

This also can support gender equity. Some work that we did in Nepal showed that if we are smart and strategic about how we promote solar pumps and how they are financed, we can encourage more women to own solar pumps. Unlike electricity or diesel pumps, which were difficult for a woman to operate, solar pumps are easy for them to run.

This is a good outcome. However, I want to end on the thought, for all of us, that time and time again history shows that almost nothing is a silver bullet: almost everything comes with unintended consequences, and we should always be on the look-out for them.

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Aditi Mukherji is a Principal Researcher, and is based in the International Water Management Institute (IWMI), India office. Before this, she led the Water and Air Theme at the International Centre for Integrated Mountain Development (ICIMOD) in Nepal. She is the coordinating lead author of the water chapter of the 6th Assessment Report team of the Intergovernmental Panel on Climate Change (IPCC). She is an associate editor of the journal *Climate and Development*, and is on the Editorial Board of the journal *Water Security*. She has over 18 years of experience working on policies and institutions of water resources management with a special focus on the water–energy–food nexus. She has published over 50 peer reviewed papers. Aditi has served as a Permanent Consultative Committee member of GEF-FAO's Groundwater Governance project hosted by FAO at Rome and is a Board member of an Indian research NGO called SACiWaters. She is the first ever recipient of the Borlaug Field Award (2012), which recognises "exceptional, science-based achievement in international agriculture and food production by an individual under the age of 40 who has clearly emulated the same intellectual courage, stamina and determination in the fight to eliminate global hunger and poverty as was demonstrated by Dr Norman Borlaug as a young scientist". The award is endowed by the Rockefeller Foundation and given by the World Food Prize Foundation, USA. Aditi is a human geographer by training and has a PhD from Cambridge University, United Kingdom, where she was a Gates Cambridge Scholar.

Weathering the 'perfect storm': transforming cities into water catchments and urban farms

Marc Noyce
Biofilta Pty Ltd

Abstract

This paper outlines the work of Biofilta in advancing a soil-based urban farming method that is scalable from household to community-scale food production. Biofilta was selected from a global search of 280 applications across 74 countries in 2017 by LAUNCH Food, funded by DFAT and USAid. All products are made in Australia and the new Foodcube system is made from recycled food-grade plastic that was destined for landfill. Biofilta has demonstrated that the sealed food growing system works in Tuvalu where water availability, space constraints and robust technology are issues facing many similar communities. DFAT has now issued a contract to implement larger-scaled community gardens using the Foodcube to create a circular economy, close nutrient loops and showcase to the world how appropriate the technology is for urban agriculture. Statistics of other gardens being grown in urban car parks showcase how little space it takes to grow the yearly recommended amount of vegetables for an adult according to the World Health Organization. Biofilta is a small private business based in Melbourne. The owners want to expand and partner with organisations across the world to deploy urban agriculture and help smallholders make an income and raise nutrition levels within the community.

At Biofilta we demonstrate how to grow food in difficult places and small spaces, using recycled plastic growing-units; we also clean stormwater through biofilters, to a standard sufficient for irrigating.

Figure 1 (overleaf) shows an example in Fitzroy Gardens in Melbourne where we suck in stormwater and by treating it with a vegetated sand filter we provide a million litres-worth of water for irrigation overnight. This system produces 70 million litres-worth of potable water offset per annum, with a 15-year payback. We can do that in a very small area: this system takes up one-tenth of what a wetland would take up, which is ideal for cities which lack spare land.

Figure 2 shows another example in Melbourne; this channel up until the 1960s was conveying sewage out to the water treatment farm at Werribee. We now collect the stormwater from the nearby developments and filter that inside what used to be the open sewer, and the product is water for landscapes.

About five years ago we decided to combine our expertise in water and in food-growing systems. We were concerned about the way people were less and less growing food in urban areas, generally because they said they lacked the time, or lacked the space, or lacked the expertise; and they found supermarkets so convenient. We wanted to do something about that.

This paper has been prepared from a transcript and the illustrative slides of the presentation.

Figures 1, 2. Groundwork (left) and final appearance (right) of the system in Fitzroy Gardens; and (below) the channel leading to Werribee water treatment works, south-west of Melbourne.

Traditional garden beds have kept humans alive for the last 10,000 years, with water being applied from the top of the soil and gradually leaching out. The system is labour intensive, conducive to weeds, and a water-intensive way of growing food. By contrast, the wicking bed system of horticulture provides water from bottom up instead of top down (Figure 3). That keeps the soil nutrients and water in check and available. Nothing is lost; it is a sealed system, though there are some drawbacks.

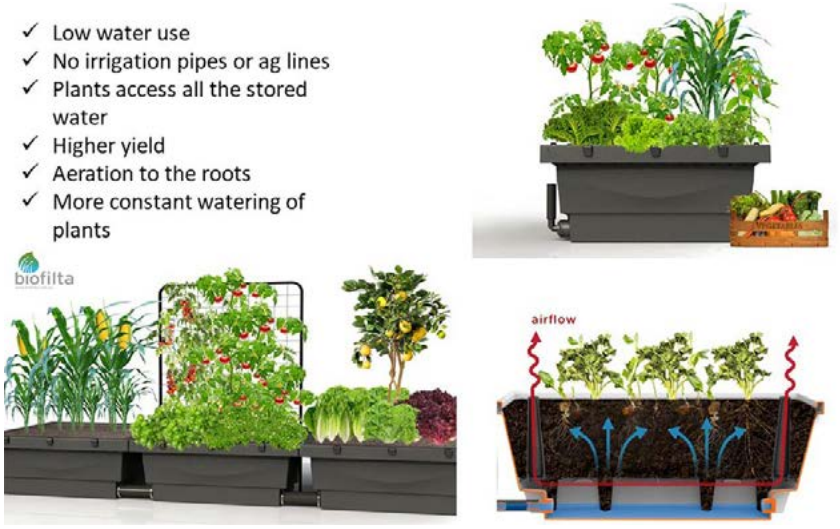


Figure 3. Advances in wicking gardens.

In Biofilta we have re-engineered the wicking garden bed system to overcome some of the drawbacks, and in 2017 the LAUNCH Food challenge, run by the Department of Foreign Affairs and Trade's innovationXchange and USAid, chose our system as a winner.

We were already growing vegetables in very modular, very spatially efficient wicking garden beds. Then in 2018 we set ourselves the target of growing 150 kg of food – enough for one person over a year, according to the World Health Organization – in a single car parking space. We tested the idea using two car spaces (in case one was too small) and in six months we achieved our target yield (Figure 4). Since November 2018 we have harvested over 350 kg-worth of food out of that small area.

Figure 4. Growing one (or two) years' supply of vegetables in one (or two) car park spaces.

Tuvalu

In Tuvalu, on the low-lying atoll Funafuti (capital of Tuvalu), where saltwater comes out of the ground, we have now showcased wicking self-watering modular technology using our 'Foodwall', a raised sealed food-growing system. Here we thought the biggest challenge would be water supply, but it turned out to be soil because the area has 3000 mm annual rainfall (collected in rainwater tanks) but the soil is coral scree, very saline and with a high pH, unsuited to vegetables. Green waste either goes to the pigs or is mixed with other waste in low-lying dumps often inundated by seawater. Traditionally vegetables in Tuvalu are grown in whatever medium you can collect, including coconut husks.

In mid-2018 we set up our Foodwall (Figures 5, 6), using local compost as growing medium, in two stages – July and September – and every four weeks we were able to harvest vegetables out of a space that could not grow vegetables beforehand. That has been affecting a lot of lives over there, which is very satisfying.

Tuvalu, in fact, has a lot of resources in plant and animal materials, and ACIAR will help set up a viable system for using those resources to grow food. Once people have a 'recipe' that can be reproduced and they get something out of it, they will maintain it. There is certainly demand for vegetables grown at home-scale; we had people lining up to get their allocation from the Foodwalls.

Figure 5. 200 Foodwall Step units (100 m^2 in total) growing vegetables in Tuvalu.

Figure 6.

We learnt a lot out of this trial: that sometimes the beds need to be shaded during hot periods, and that heat build-up in the planter boxes can be an issue; that compost supply is critical to provide nutrients; that education and good partners on the ground are very important; that perception is also very important.

In summary, sustainable food-growing needs on an island are: (i) access to water; (ii) growing medium such as compost; (iii) replenishable nutrients for plants; (iv) seedlings; (v) a closed nutrient loop; (vi) land area; and (vii) education.

Foodcubes

To scale-up our growing system we have developed the Foodcube, which we make from recycled food-grade chip-packet film that was going to go landfill. Two local companies in Melbourne have invested $6 million in tooling and construction to create the Foodcube. Figure 7 shows Foodcubes bound for Tuvalu, with no packaging or waste.

Figure 7. Foodcubes , deconstructed (left), and loaded in a container for Tuvalu.

Figure 8.

The photos in Figure 8 show where we plan to deploy Foodcubes: schools, homes, city rooftops and urban farms. The sky farm pictured will be on a 2000 m² roof top on a Melbourne carpark, and we also plan to set up an education centre for urban agriculture. We want schools to grow food and reconnect the community with food-growing, because in one generation we are losing understanding about where our food comes from. Closed-loop urban farms in urban communities are the way to go.

Marc has over 20 years of experience in the water industry and is the Chief Executive Officer of Biofilta Pty Ltd, a Melbourne based water sensitive urban design and urban food product supply company. With a mission to 'turn our cities into water catchments and urban farms', Marc is passionate about combining engineering and horticultural skills to solve urban sustainability challenges. Marc grew up on a working market farm and likes to encourage everyone to grow their own food in a sustainable manner.

Q&A

Chair: Chris Tinning
Panel: Aditi Mukherji, Marc Noyce

Q: Jack, The University of Adelaide
I think in the last week or so, President Joko Widodo announced that they're going to move Indonesia's capital city Jakarta due to the groundwater issues and the city sinking. Do you have any suggestions on how Indonesia or other countries can plan to prevent these issues happening again?

Q: Peter Wynn, Charles Sturt University
Is there any way, or have you thought of using grey water from urban areas to send out into the adjacent rural areas; and also, could you comment on desalinisation as a potential source of water for agriculture?

A: Aditi Mukherji
I think there is a lot of scope for recharge of groundwater in urban areas, except that because we have built up everything it becomes really tricky. In some of the discussions that are going on, around urban renewal, urban regeneration, you are building your infrastructure in such a way that it also allows groundwater to be recharged. I don't specifically know about Indonesia, but most cities in South Asia, for instance, have been also building on all the drainage lines of the hydrological cycle and then people are so surprised, and ask "Why are floods increasing?". I think, proper urban planning is the way to go.

In India, any vegetable you're eating, chances are it's been grown with untreated grey water because pretty much all the developing countries around the world do use grey water to grow crops, especially vegetables. I was recently in Switzerland where it is usual to treat stormwater to such an extent that it's drinkable. They were thinking of treating some water less thoroughly so as to use it for growing crops. Also in Ghana, and in Ethiopia, and in a lot of Asian cities, there is a lot of reuse of water. As for desalinisation, I think Chennai for instance is seriously considering desalinisation as one of its various options, but it still remains expensive.

Q: Tony Fischer, CSIRO Canberra
Dr Mukherji thank you for that great overview of water in India. To give us an idea of the extent of over-pumping, is it 5%, 10%, 20% – did you have a rough idea? For example, for the Punjab or Haryana?

A: Aditi Mukherji
No, I won't have that number; I can look it up, but in relation to long-term renewable recharge. Many of the districts in Punjab have over-exploitation of 250%, which is 250% more than the volumes being renewed.

Q: Razlin, Southern Cross University, NSW
Two questions for Marc. The species that are able to be planted in your garden beds, are they limited? And, do you have particular interest in global niche crops

This Q&A report has been prepared from a transcript.

or minor crops that have cultural significance, especially in areas such as sub-Saharan Africa and south Asia?

A: Marc Noyce
Good question. Our initial product is only 200 mm deep. The Foodcube is over 300 mm deep and then it has its soil cones, so it's 500 mm top to bottom. The taro that is sold in Tuvalu (i.e. not the large swamp taro) grows in a 150 mm pot. So the Foodcube's actually quite appropriate to grow traditional crops.

Q: Ros Gleadow, Monash University
Marc, you mentioned briefly that temperature could be an issue, that the soil could get too hot. I'm wondering if you've come up with some solutions or ideas for moderating the heat for the containerised growing?

A: Marc Noyce
The food walls that we have over there, they're suspended in the air and they can heat up. The Foodcube is on the ground. We expect that that will have a heat exchange opportunity with the ground itself, and it's much larger in thermal mass as well. They can be combined with some shading – and we can potentially produce them with different colour options available. Part of our trial is to really understand that temperature build-up and its dissipation and its effect on plant growth; so we'll be monitoring that very closely with ACIAR.

Q: John Hancock, Research for Agriculture
Marc, I'm presuming that you've probably encountered the venture capital scene through some of the work that you've been doing on the agricultural goals that we're trying to achieve. Do you have any key take home messages for us today on the capital-raising journey you've experienced? In the venture capital scene or the private investment sector in agriculture in Australia?

A: Marc Noyce
In fact, we self-funded all our development within our private company. Whatever product we develop we self-fund so we don't have any debt. But if you go for venture capital you then give up a certain percentage of your company to someone else and you've got to be willing to take on that additional scrutiny, if you like, and also other partners coming in to satisfy the venture capital company. You just need to balance up the level of control you're willing to give up, for accelerated uptake. Does that answer that question a little bit?

Environment–schmironment: climate change through a finance & liability risk lens*

Sarah Barker
MinterEllison

Abstract

First it was activist investors. Then mainstream shareholders. And now finance markets, insurance companies, regulators and even auditors are demanding that companies actively address their climate-related financial risks. But why this shift from 'ethical fringe' to 'financial mainstream', and what does it mean for corporate governance, strategy risk management and disclosure? And how can seemingly divergent national policies, regulatory practices and financial market signals be commercially reconciled? This presentation examines climate risk from the unique perspective of a corporate lawyer, director of a large institutional investor, and faculty member of the University of Oxford's Sustainable Finance Programme. It focuses on emerging corporate governance issues for FY19, from:

- international regulatory developments: the EU's Green Taxonomy, the UK's Net Zero Law, and signalling by central banks and prudential regulators;
- international financial market trends: integration of climate-related issues into credit ratings and commercial loan margin adjustments;
- litigation trends beyond planning and permitting: climate-related negligence, nuisance, directors' duties and securities fraud claims; and
- annual reports: heightened investor expectations around TCFD-aligned disclosures, and new regulatory guidance on the integration (and audit) of climate-related assumptions in balance sheet accounting estimates.

You might be wondering why the Crawford Fund has asked a corporate lawyer to speak about climate change to a group of people many of whom already have PhDs in this area. You would be right: I don't care about the environment; I don't care about the community. But I do care about money and I care about risk, and that's the lens I bring when I look at climate change.

I'll start by looking at the different categories of financial risk associated with climate change, and focusing on, not the physical risk impacts but the responses – of financial markets, of capital markets and the real economy – to those changes. Then finally, I'll talk about the proactive approach to climate change risk management.

Climate change has evolved from an issue that was purely environmental, a few years ago, to one that is squarely a material: financial risk. There are three categories of climate-related risks declared by the Bank of England Prudential

* This article has been prepared from the transcript of the audio recording of Ms Barker's presentation, and her illustrative slides. It does not represent a formal paper, nor prepared remarks from which Ms Barker spoke.

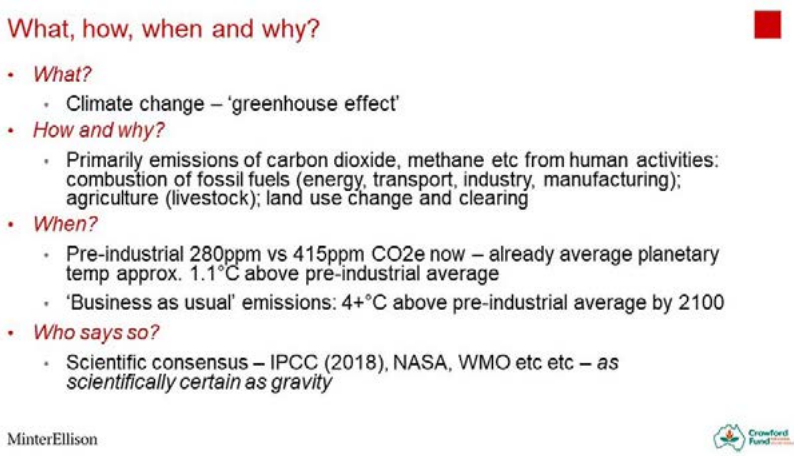
Figure 1.

Regulation Authority (Figure 1): i.e. the physical risks, the economic transition risks associated with climate change, and the liability consequences associated with a failure to manage either the physical risks or the financial risks associated with climate change.

Physical risks

Figure 2 summarises the how, why, when and who of climate change. Scientists tell us that we are already 1.1°C above the pre-industrial average in terms of climate change. Note that that's a global average: it's lower at the equator and higher at the poles, and it's 1.4°C above the pre-industrial average over the land in our mid-latitude.

I want to emphasise that the problem is already manifesting. Figure 3 shows bell curves representing the distribution of global average temperatures in 1900 (pale grey) and the comparative situations in the years 1950 and 2000 and now. The average has shifted significantly to the right, indicating that 1.1 degrees of warming are already baked into the system, and we now have a temperature range of between minus 3.5°C and plus 5.5°C: significantly more variable. And we know this across the world from our own weather experiences. Variability means uncertainty and uncertainty means risk.



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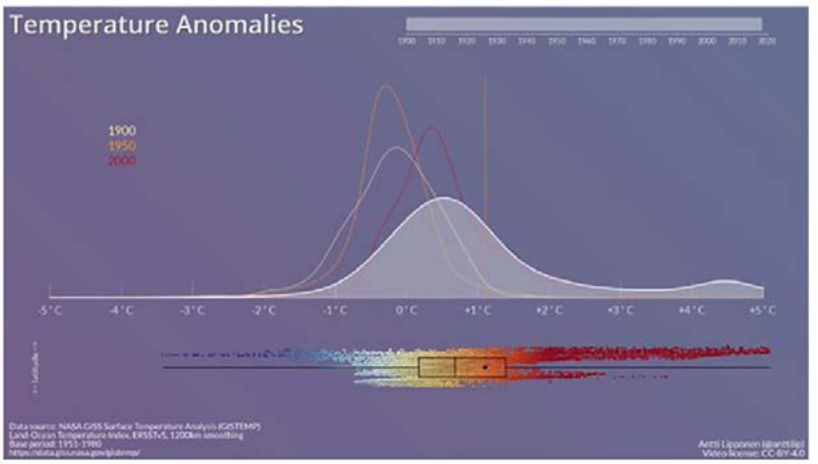

Figure 3.

The way we're going at the moment, in terms of global emissions, and if we continue to operate the way we have as an agrarian economy over the last 50 years, to keep global warming well below 2°C we have to get to net zero by the middle of the century – in every aspect of life.

I want you to start thinking what that means from a monetary perspective. What does it mean for water scarcity? What does an increase in average temperatures mean for your ability to continue the work of your plant and equipment, for spoilage, for soil denitrification, for ocean acidification, for freshwater purification, for disease and pest control? The Queensland floods of 2011 caused *more damage* in terms of social cost, in terms of family breakdown, in terms of suicide, in terms of mental health, than it did to the physical assets. What does changing climate mean for the integrity of your supply chain?

Economic transition risks

Again, the Bank of England has very conveniently given us three categories in which to think about economic transition: policy and regulatory shifts, technological developments, and a shift in stakeholder preferences.

Policy and regulatory perspective: In Australia, we had – and then didn't have – a carbon tax. England has introduced into law a 'net zero emissions by 2050' policy. It's not a policy; it's not a target; it's in their law. A few weeks before that, New Zealand did the same thing. They have got a target of up to 47% reduction in biogenic methane by 2050. If New Zealand can achieve that, other countries can also. What is that going to mean for the relative competitor that maybe is inherently more emissions-intensive?

All the elements of this 'snowball' of policy changes are being driven by the Paris Agreement. **The Paris Agreement** includes Australia. (The only two countries that didn't sign up were Syria and Nicaragua.) For that Agreement, the signatories all agreed about the criticality of limiting global warming, and to commit to policies of their own that would be consistent with limiting global warming below the critical level. The Agreement includes a five-year review – a

ratchet mechanism – meaning that, from 2020, the parties have to come back to the table with more ambitious emissions-reduction policies.

There is a second part to the Paris Agreement: all these countries also signed up for the global economy to be operating on a 'net zero emissions' basis in the second half of this century. The problem is that we have let the problem run, and the IPCC now tells us we have to make big progress before the second half of the century – that is, not by 2099 but by 2050.

Stakeholder shifts: There has been plenty of talk about the red meat sector and its impact on agricultural emissions. It is part of a far broader movement, primarily led by Millennials, who are concerned about ethics and values.

We now see rapid shifts in public perception, such as on single use plastics – that shift took only one year, and now you get evil looks if seen using a plastic drinking straw! A year ago that wasn't of concern at all.

The chart in Figure 4 has orange and yellow bars: orange for change needed by people in the UK, and yellow for the same change at global scale. It's telling us that to keep global warming to well below 2°C above preindustrial average, we should modify our diets because of the inherent emissions involved, and that will affect business in the agri-sector. Has anyone tried Beyond Meat? a Beyond Burger? They taste so good!

Particularly in Australia, a lot of the shift in stakeholder attitudes has been driven by equity markets, shareholders – not because they care about polar bears or penguins, but because they care about money and continuing to make money for us. They are asking businesses: How do you continue to thrive in this transition to a low carbon economy? Tell us your plan. We want you to keep making money because *we* need to keep making money.

BlackRock, for instance, is so big it owns 7.8% of every listed company on the planet. They are actively engaging with a consortium of investors, and engaging

Figure 4.

with the companies they invest in, seeking disclosures in accordance with the recommendations of the Taskforce on Climate-related Financial Disclosures published by the G20 financial stability board after the Paris Agreement was signed. They asked Michael Bloomberg to make recommendations about how a company could assess and then disclose to the market.

The key recommendation in this framework is to do stress testing and scenario planning on a forward-looking basis.

What if ...?

At one end of the spectrum, if we aim to limit global warming to 1.5ºC above the preindustrial average, that necessitates the entire global economy decarbonising within the next couple of decades. What does business look like in that scenario?

At the other end of the spectrum, what if we continue business as usual on an economic transition platform, with four degrees of warming by the end of the century? How does our business look then?

Credit rating agencies that make assessments of how likely people are to default on their loans have examined countries' sovereign risks associated with climate change. For populations living within 5 m of sea level, Australia does not do well. Nor do we do well in the category 'agriculture and extractives as a share of GDP'.

Itaú, a Brazilian bank, went through its lending book and looked at its 14 largest agri-business loans, and assessed, all else being equal, what climate change would mean for water scarcity in the region in which these clients grew crops. Their findings are not pretty, other than for Client 3, perhaps a coffee plantation at the top of a mountain; perhaps the only place that will be supplying coffee in 20 years' time.

In Australia, the Commonwealth Bank annual report for 2018 shows its analysis of its lending portfolio on a 5 m x 5 m grid of the country. It assessed the increase in risk associated with climate change due to coastal inundation, freshwater flooding, bush fire, wind shear and – the one that really surprised them – soil contraction (because when some clay soils dry out they shrink markedly).

More relevant for this conference is their 2019 Annual Report analysis of change in farm profitability, *with* adaptation and *without* adaptation, looking ahead to 2060. The scale goes from –50% (brown) to +50% (green). Figure 5 (overleaf) shows the results. The good news is there is much more green *with* adaptation, such as by positive steps to build resilience into cropping.

Good news: finance opportunities

It is going to be an advantage to be able to operate sustainably. There are not only brown penalties, there are also green discounts. These are emerging particularly in Europe: for example, sustainability-linked loans, where every year your performance is evaluated against predetermined sustainability, and if you miss a target you get a brown penalty. This is now commonly in use across Europe and Asia, particularly in the agri-sector: from Danone, Bel, Olam, Wilmar. These kinds of schemes are only in their infancy in Australia.

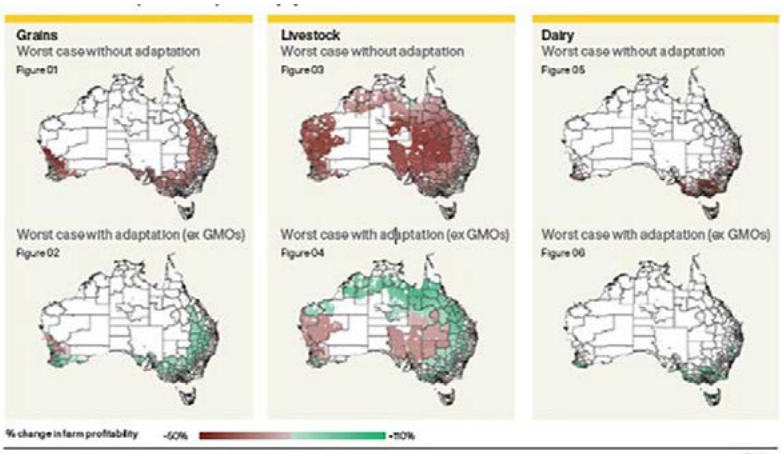

Figure 5. Climate simulation: Impact on farm profitability by 2060.
Source: Commonwealth Bank of Australia

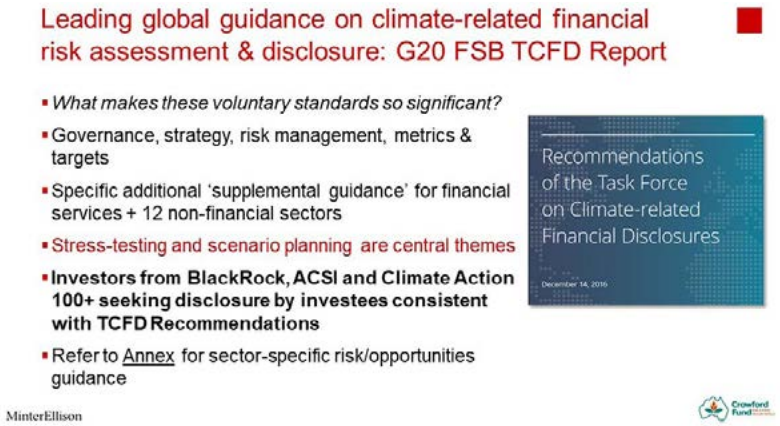

Figure 6.

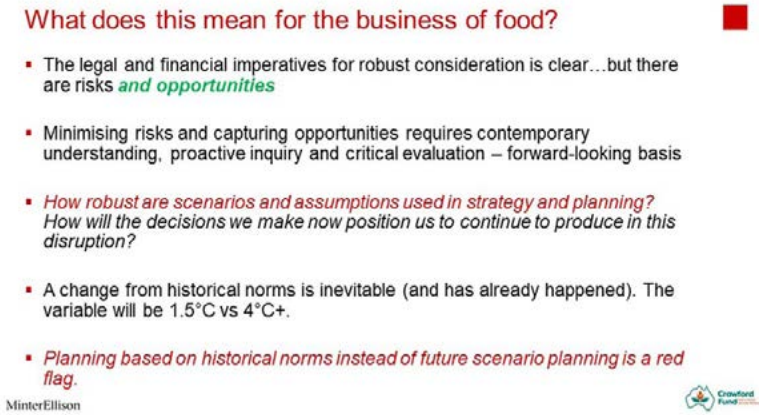

Figure 7

Practical tips

If you are adjusting your operations to be resilient to the impacts of climate change, talk to your bank about it, leverage it, lower your cost of capital and, most importantly, make sure you are doing stress-testing and scenario planning (Figures 6, 7).

Sarah Barker has two decades' experience as a corporate lawyer and is regarded as one of the world's foremost experts on investment governance issues relating to climate change. Her expertise is sought by public and private sector clients across Australasia, and by global institutions from the Bank of England to the United Nations PRI. Sarah is a non-executive director of Emergency Services and State Super and the Responsible Investment Association Australasia, and she is on the Steering Committee of the Australian Sustainable Finance Initiative. She teaches the Australian Institute of Company Directors' flagship Company Directors' Course and the Cambridge Institute for Sustainability Leadership's 'Earth on Board' program, and is an academic visitor at the Smith School of Enterprise & the Environment, at the University of Oxford. Sarah holds a B.COM (ACC & FIN), LLB (HONS) and M.ENV (HONS).

Q&A

Chair: Malcolm Thompson

Panel: Sarah Barker, Sir Charles Godfray

Chair: Malcolm Thompson
Obviously in financial markets, particularly because there's so much money awash in the markets at the moment, there are many institutions which are placing bets on the other side, who think that offering a premium or a discount for those sectors, or those industries which are responding actively to adapt to climate change. What do you say to that?

A: Sarah Barker
Last year, when questioned, asset managers, who basically invest the money on behalf of the large institutions, 95% of them said that they expected a sub-prime crash in markets over the next five years. If you talk to asset managers about that disconnect, they say, "Oh yes, but we're going to get out before the crash", to which my response is, "Well if you know when that's going to be, you've hit investment nirvana, because you know it's coming". To me it seems the big shift is going to happen because we have regulation, prudential regulation, and jurisdictions like Europe and China changing, requiring this stuff to be priced based on how sustainable you are. That's actually being driven because the European Commission is considering a recommendation, by their high level expert group on sustainable finance, to actually change the capital regulatory requirements in Europe, if they are green versus if they are brown. And to my mind, once that price signals starts filtering through, that's one of the potential triggers for the sub-prime.

Q: Dr Peter Carberry, ICRISAT, India
Sarah, thanks for your talk. You were talking about risk and uncertainty around the financial markets. I expected to hear a much more probabilistic view of what's happening. You were very deterministic, very definitive about what's going to happen. Is that the narrative you have to take in your world?

A: Sarah Barker
Yeah, that's a really good question, and obviously in 20 minutes it's a bit of a high-level overview. I think the one issue that markets do struggle with is the breadth of the uncertainty and how much it's changed already. It will change more. By how much? That's what we don't know. And so that's why the focus is very much on a range of possibilities because the fact is that no-one can tell if there might be a 20% chance that something will happen, or if it is a 10% chance that that will happen. So we do need to talk in terms of what we know for sure.

A: Sir Charles Godfray
I think one of the interesting ways of looking at the 2008 financial crisis was that it was a failure of statistics: that the correlations between different risks were not put into the models that the banks were using to estimate their risks.

This Q&A report has been prepared from a transcript.

I think there is some encouragement that the industries are taking into account some of the physical correlations that can lead to, for example, in the ag world, multiple bread-basket failures in different regions.

A: Sarah Barker
We're still not great at it though. Even just thinking about the way that we stress test portfolios, and say, "OK, what happens if there's global recession? What happens if there's deflation?". I think we could get a lot better at looking at, "Well what if there is a super typhoon in Japan?". We can't look at that in isolation because of the flow-on and secondary effects that would have all across the world. I think we do need to get a lot better at that.

Q: Male
Thank you both for your addresses. Looking at the graphs this morning of the consumption of beef in China going up linearly. How are we going to turn around and tell the consumer in China, "You're going to destroy the planet if you keep on eating that lovely beef". What sort of solutions can we start looking for?

A: Sarah Barker
From stress test scenarios, we think that soon the inevitable policy response scenario will be 'destructive decarbonisation'. That means we think the world will get to a point in a few years' time where everyone goes, "Oh, Armageddon, bother! War footing!", and everything has to decarbonise 'overnight', and countries will impose a carbon tax levy, effectively 'overnight'. In China, where they still have very much a command-and-control system of government with five year plans, if in a five-year plan they decree "No-one can consume more than two kilograms of beef a year", then that is what will happen. The people who will be most affected are the middle class in China and India and the developing world, who are becoming richer and want to live like we live, of course. There are two alternatives here: either that will continue and there will be entire global collapse, which doesn't really benefit anyone's economy; or we will have that sharp correction.

A: Sir Charles Godfray
I've just a few comments on that. Chinese dietary guidelines are changing and recommending less meat, which is a baby step but is a sign of things to come. And the 'Beyond Meat' company has done extraordinarily well, and there has been investment from traditional meat companies. I think that they're looking at the potential regulatory risks ahead and taking action now, before government does.

Q: Female
In terms of the modelling and looking at the economic impacts and what insurance companies and banks are considering, with the agricultural sector in particular, we see climate change getting more challenging and that science and especially research and development is not necessarily keeping up. So how much is the investment the countries are making in research and development also factoring in what the private sector and modelling are looking at?

Sarah Barker during her Keynote address in the Great Hall of Parliament House.

A: Sarah Barker
I haven't thought of it like that before. No one ever invests enough in R&D; that's the way it is. But there are a lot of statistics around now, particularly in the US, where people are trying to build levee banks to protect their own properties, and that then compounds flooding downstream, etc. There's a lot of data coming out of the US now about the economic dollar value of prevention versus recovery, because they've also got national flood programs where if you do get flooded the federal government will pay you to rebuild on the same spot. But I think it's a really insightful comment that we're really not investing enough, anywhere near enough in this.

A: Sir Charles Godfray
I'm so glad it's a corporate lawyer, not the university professor, arguing for money going into research!

Q: Malcolm Thompson
I think it's interesting that the OECD recently pointed at the amount of subsidies that are going to agriculture worldwide. A proportion of that could be dedicated to R&D; they make the argument that that would be a much more effective way of building resilience.

Q: Female
Do you come across the 'de-growth' argument? I know it's still a very niche kind of a discussion. I mean, it makes sense that you cannot keep growing without limit.

A: Sarah Barker
Growth, in the way that we know growth, cannot continue, and that's just a mathematical proposition. The Earth can't support us. So I suppose there are

two alternative things that will happen: either there'll be the global collapse, which will force everyone to live within the planetary means, or, and this is where my hope lies, we do move to a far more circular system of economy. Because if that's the case then from an economic perspective resources are effectively unlimited. But from a physical limits perspective, growth can't continue as it is.

A: Sir Charles Godfray
I completely agree with that. I think the narrative, and how you phrase it, is really important. Nick Stern, for example, talks very much about decoupling. There's a straight economic version; there's also a social norm aspect to it: what we consider to be wellbeing, what we consider to be good life. Going back to your point about the Millennials, I think they're redefining some of those concepts. There is a lot of interesting new economic thinking about exactly what is utility in a modern sense.

Q: Tony Fischer, CSIRO Canberra
Can you discuss a little bit more the economics of carbon sequestration, especially in landscapes, and apart from the Armageddon situation that you describe, how can you see it evolving?

A: Sir Charles Godfray
This isn't really my area. We have to have a realistic carbon price; we've been pretty hopeless about that in Europe. Putting a proper price on carbon wouldn't solve everything, but it would be a tremendously good incentive. I think that by mid-century we may be looking at, not only carbon sequestration, but active carbon removal, carbon capture and storage.

Q: Josie Ginty, The University of Melbourne
Sarah, when you were talking about the deterministic approach in terms of the changes you said have to happen in the agricultural industry, do you take into account, when looking at those costs and benefits, the ethical changes that are coming with that as well? Obviously there's going to be human rights and animal welfare consequences, in the worst case scenario. I am wondering if and how you account for those costs?

A: Sarah Barker
Absolutely, although there is no cost as high as a four-degree world, because that's not good for anyone, but I think you are absolutely right. We are seeing at a micro level the impacts on the communities where coal-fired power plants are shutting down and there haven't been plans to transition the industry in those areas. It's going to be that on steroids, quite frankly, but it's not that we have to stop that pain. The transition has to happen. There are two alternatives: it happens or we're 'stuffed', and that would not be good for anyone. Transition is good for everyone! It might mean different things for different people, but it's good for everyone. Rather than starting from where we are now and thinking about transition in incremental shifts, I think, we should look at the target and ask what are the options for getting there? And what are the decision paths that we have in front of us now that are either maladaptive or enablers to getting us to that state?

Q: Wesley, The University of Western Australia
Thanks so much for your talks. You've talked about the financial costs of global warming and no country is on track to meet their climate change obligations and the biggest economies in the world aren't anywhere close, so is there a point where the private sector says OK, we're going to leave the governance behind and go it alone?.

A: Sarah Barker
Really the market is leading on this; it's quite extraordinary, and if I was a betting lady I would bet on the money every time. We're looking at price parity between electric vehicles and cars with internal combustion engines in the UK by 2022. Once that happens who cares? In 75% of cases, in developed countries and China, it is already cheaper on a marginal cost basis to shut down your coal-fired power utility and install solar with storage. So those tipping points are very, very close. It would be better if the policy settings were efficient and conducive to the transition, but the market is moving ahead anyway. You're not going to get a coal-fired power plant funded in Australia. You're not going to get it insured. That's the market.

Chair: Malcolm Thompson
OK, we're going to need to finish there. Please join me in thanking our keynote speakers again.

Conference synthesis

Professor Timothy Reeves FTSE
The Crawford Fund & The University of Melbourne Dookie Campus

In summarising the key messages arising from this conference it would be remiss of me not to start with the wonderful Sir John Crawford Memorial Address delivered last night by **Professor Ross Garnaut AC**. He so clearly described the nexus opportunity that is there for the grasping, between productive, profitable and sustainable farms delivering high quality products to enhance food and nutritional security and at the same time sequestering carbon in our depleted soils. This would not only help to reduce greenhouse gas (GHG) emissions, but also to restore soil health across our farming landscapes – a national and global revolution with regional and rural Australia at its centre. A stimulating and optimistic manifesto! His only doubt about achieving this nexus opportunity – a recurring theme throughout the meeting – was whether we as a nation can seize this great opportunity. Doing so should be the first action item arising from this conference, and we may as a result even have to tweak one of our iconic lines to 'Beneath the Eucalypt we stand, a sprig of Mallee in our hand'!

Today at the conference we have also been treated to some wonderful and stimulating addresses with clear messages about the challenges and great opportunities of nexus thinking and actions.

Professor Sir Charles Godfray in his morning Keynote address declared 'It's game on!'. Charles eloquently and forcefully outlined the need for a new revolution in agriculture of the same magnitude as the Industrial and Green Revolutions, that would not only boost productivity but also radically improve resource-use efficiency and sustainability. He stated that we needed to reduce waste, and for me (TGR) the fact that globally we waste around 30% of total food production is not just an enigma, it is in many instances a disgrace. I believe that in the Western world we have lost our respect for food and treat it as a cheap commodity, whereas in the developing world there is still great respect for food. Charles said that we also need to make hard decisions about diets and consumption patterns. He called for globalisation of our food systems to provide both public and private benefits, and to me (TGR) this means free trade not only in safe, nutritious food products but also in the knowledge of how to produce it sustainably – the business of ACIAR and its wonderful partners.

Charles firmly believes that these ambitious goals are attainable, but only if we understand the risks and the challenges and build the political will to act.

The modelling being conducted in the Oxford Martin School, which he described, is just what is required – being able to ask and answer the questions, 'What would the outcomes be if we all ate healthily?', or 'Can we feed the world within planetary boundaries?'.

What keeps Charles awake at night? – the huge differences in the proportion of incomes spent on food between developed and developing country families; the

Professor Tim Reeves provided this paper.

rise and rise of mega-cities where more and more people are waiting for their food to be delivered, but with fewer and fewer people out in the rural areas producing that food; food riots; and overall the situation of food and nutritional security in many parts of Africa.

Our next session was entitled 'Weathering and halting the perfect storm' and the overview was delivered by **Dr Bruce Campbell**, leader of the CGIAR CCAFS* Program. Bruce treated us to a talk with three components: 'Malthusian pessimism'; inspirational stories of achievements to date; and, perhaps most importantly, how we need to do things differently if we are to stimulate the actions necessary to achieve urgently required actions in the future. He strikingly reminded us that 'we only have 11 growing seasons ... to achieve the Sustainable Development Goals' … . For me, there were many important messages but the most important may be the changes in the CCAFS partnership paradigms and modalities that he very clearly described. Firstly, the greater emphasis on the strength of the partnership – 'If you are not clearly committed to change, then we may not want to work with you' – and secondly, the urgent need for a new and much more participatory and circular partnership system to achieve food system transformation. Bruce illustrated this well with his 'Fostering enabling policy and institutions' slide [see page 39 this proceedings].

Bruce's presentation was immediately followed by a great example of such a new modality from **Professor Alice Joan Ferrer**, also of CGIAR CCAFS. She described the success of the Climate Smart Villages initiative with its participatory local inputs into the ways forward.

Professor Ferrer was followed by **Dr Di Mayberry** of CSIRO who picked up a theme introduced earlier by Charles, of reducing GHG emissions from red meat production in Australia and developing countries through better land management, input-use efficiency and carbon sequestration. It however also raised the question from the floor of whether better sustainability outcomes could be achieved if the land was destocked and used in a different way, perhaps for re-forestation where potentially there are 58 million hectares potentially available? Dr John Angus also from the floor, was concerned about the social consequences from such decisions which were primarily aimed at environmental outcomes. To me, it is clear that the trade-offs between environmental and social impacts require detailed consideration, as it is critical that no one is left behind by such decisions.

The next session of the conference was 'Crops, drops and climate challenge', introduced by the overview address of **Dr Ajay Mathur**, Director of The Energy and Resources Institute in India. He talked about using energy efficiency to address the 'perfect storm' and reminded us of the unintended consequences of past actions, in this case the 'Green Revolution' which had resulted in much greater crop yields, but also much greater water and energy use – the latter for both pumping water from increasingly greater depths as tube wells deplete, and also for fertiliser production.

* Climate Change, Agriculture and Food Security, CCAFS

Professor Timothy Reeves giving his Conference Synthesis in the Great Hall of Parliament House.

It's been calculated that around one-third of the energy required to feed a person in the Western world is actually used for fertiliser production, particularly nitrogen fertilisers. And yet we have a proven and sound alternative way to lift soil nitrogen that does not require huge energy inputs – biological nitrogen fixation by legumes! There has been a demise in the use of legumes in our farming systems and this needs to be rectified as they would not only supply the diversity in diets mentioned by Sarah Barker, but legumes also make economic and environmental sense in sustainable farming systems.

A key point of Ajay's presentation was the exciting development of solar powered irrigation pumps that allow farmers the choice of selling the electricity generated or using it to add more water to their crops, thereby providing an alternative to unsustainable pumping of tube wells. It was a very interesting and informative presentation.

Dr Jim Woodhill, DFAT SDIP adviser, followed, and he reminded us that 90% of freshwater in south Asia is already used for irrigation and that doubling food production will certainly not be achieved from increased water usage. The most important point that I took from Jim's presentation was again the need for new approaches to ensure that political innovation, institutional innovation and technical innovation are implemented and that the Sustainable Development Investment Portfolio (SDIP) provides a structured and well organised framework for this to be successfully achieved.

The final presentation in this session was by **Dr Oudom Phonekhampheng** of the National University of Laos, who gave a further example of the unintended consequences of actions taken, when he described the impacts on fish movement of the multiple dams and other barriers across waterways of the Mekong Basin. The solutions developed in his work were based on a variety of 'fish passes' to facilitate movement for various types of fish. For me, the most shocking aspect of Dr Oudom's presentation was the plethora of dams on the Mekong already and, more alarmingly, the number planned or already under construction!

This afternoon the first session was on 'Circular food systems and solutions' and in her overview **Dr Aditi Mukherji** (of the International Water Management Institute) emphasised the importance of policy settings. She stated that to address climate change, global policies were critical, but for water management more local policies were required. It prompted me to think that we need to modify that old expression to now read 'Think and act globally and think and act locally'. For example, she pointed out that different groundwater electricity regimes across India require different solutions, and that being strategic when promoting solar pumps for groundwater could improve gender equity while adding to food production. Nevertheless, she made it clear that brave decisions were required around current and future water usage, again reminding us that 'history shows that almost nothing is a silver bullet' and we should all be on the lookout for unintended consequences.

Marc Noyce, CEO of Biofilta, then presented the exciting developments with water sensitive urban design and sustainability practices that company is achieving, including their water-efficient urban food production systems. It is very encouraging not just for Australia but also for developing countries, and his example was vegetables grown in Biofilta products (made from entirely recycled materials) in Tuvalu.

The afternoon Keynote address, which opened the final session of the day, was presented by **Sarah Barker** from Minter Ellison, who dramatically described how climate change is already firmly embedded in the financial world as a reality and not something that may happen. She talked about the huge losses already being caused by extreme events and the increasing risks from these in the future and also the impacts of rising sea levels, floods, bushfires, and drying cracking soils (impacts on building foundations). It emphasised for me that leadership in addressing climate adaptation and other key issues must now come from industry, communities and influential individuals, with the hope that governments will follow up with policy settings that facilitate and provide a supportive policy framework.

So, my conclusions are:

- that food and nutritional security are humankind's greatest challenge for the coming decades, as global population continues to increase at the rate of around 160 people/minute all of whom must have enough nutritious food to live healthy and productive lives.
- that nexus thinking and actions are critical, and that now – more than ever before – we must consider the agriculture–food–nutrition–human health–planetary health nexus as critical for our decision making.
- the overriding message from the conference is optimistic, but 'business as usual' is no longer a viable option. However, as we make the necessary changes, we must ensure that no one is left behind.
- a major opportunity is that sustainably intensified farms with more diversity, enhanced soil carbon and nitrogen levels are not only more productive and profitable but also more climate smart and more resilient to climatic and

economic shocks. In other words, all of the elements for better productivity and healthier ecosystems are pulling in the same direction.

- the question remains: 'Will countries have the political commitment and agility to address and seize these urgent and exciting opportunities?'.
- lastly, but very importantly, we have had many reminders that 'agricultural sustainability is a moving target' and that we cannot make the mistake of thinking that the *status quo*, however good it looks, will remain sustainable as other factors change.

My recommendations are:

- to seize the opportunity to diversify our agricultural systems for carbon sequestration and improved soil health, through the integration of crops, forages, legumes, livestock, shrubs and trees.
- to promote the continuing importance of the development of disruptive technologies.
- to urgently develop new paradigms to increase the adoption and impacts of beneficial changes in agricultural development with our partners, through such new approaches as outlined by CCAFS and SDIP.
- to ensure that we have policy cohesion across the key nexus elements, as it is no longer acceptable nor appropriate to make policy decisions on water or energy or agriculture or climate, or other areas, in isolation.
- to ensure that we increase our efforts in the sustainable intensification of our agri-food systems in order to 'produce more with less', or as a colleague in the UK – Professor John Porter – recently suggested to me, it was perhaps better to change this to 'produce enough with less'.

Thank you to all our great speakers!

Tim Reeves has worked for over 50 years in agricultural research, development and extension, focused on sustainable agriculture in Australia and overseas. His international roles have included: Director General of the International Maize and Wheat Improvement Center (CIMMYT) based in Mexico (1995–2002); Member, United Nations Millennium Project Task Force on Hunger; Member, European Commission Expert Group for Evaluation of H2020 Projects; and Senior Expert with the Food and Agriculture Organization of the United Nations (FAO) working on Save and Grow – sustainable intensification of smallholder agriculture. Professor Reeves was a Board Director of GRDC; the Future Farm Industries Cooperative Research Centre (CRC); the Molecular Plant Breeding CRC; and he is currently a Board Director of the Crawford Fund. Tim is now Professor in Residence at the Dookie Campus of the University of Melbourne, and in 2016 the University awarded him a Doctor of Agricultural Science *honoris causa*. Tim is a former President of the Australian Society of Agronomy and in 2017 the Society awarded him the prestigious Professor C.M. Donald Medal for lifetime achievement. He is currently a Fellow of the Academy of Technological Sciences and Engineering.

Closing comments

Dr Colin Chartres
The Crawford Fund

Last night Ross Garnaut indicated the importance of land management to sequestration of carbon, and today, as Tim Reeves has just so eloquently stated, we have had a lot of the detail filled in regarding key issues and solutions with respect to the impacts of climate change on agriculture, what needs to be done and how it can be delivered, with some practical examples. We've also heard of risks and unintended consequences of change.

Climate change is the driver of the issues we've been talking about. Clearly, these issues relate to water, which is directly related to climate, to population growth, and to energy, leading to a wide range of environmental and agricultural challenges that we have to overcome. It doesn't matter what is causing climate shifts, whether they are human-made or not. If we're going to solve the challenges created we need to do it together, and we need to take a non-partisan approach.

If climate change doesn't eventuate fully, if we don't go to two degrees warmer, or even higher, it doesn't matter. As Tim has just pointed out, we are going to do things which are going to make agriculture more efficient, more sustainable.

Those who will put into action the solutions we are talking about will largely be people under the age of 30. And a great thing about our conferences is that over recent years there have been increasing numbers of delegates of that age – even possibly 100 at this conference alone. It's a great challenge they face, and I hope they are really excited to be at the beginning of a career with so much to achieve, and so much potential to make a difference.

Older researchers, academics, policy-makers, can still take an active part: we can mentor, we can guide and we can also play advocates to the powers that be, to get our bureaucrats and politicians to listen and act.

A message that everyone here should be putting out to our politicians is that we need action, it needs to be non-partisan, and we can actually achieve something very considerable when we put our heads together in this area.

Thank you

When we meet as a Crawford Fund board, we start talking about next year's conference topic. Organising this annual conference takes us about a year. It's not just what happens here and now on the day. The board, and a number of individuals who act as a conference committee, help find speakers and ask these speakers to attend, before we move into the more detailed planning and preparation.

I'd like to thank Ross Garnaut who filled in at extremely short notice and delivered such a polished performance last evening. And thank you to today's

This paper has been prepared from a transcript.

Dr Colin Chartres during his closing comments in the Great Hall of Parliament House.

speakers who have all done a brilliant job – whether keynotes, overviews or case studies.

I also want to thank all of you in the audience not only for attending but also for your very articulate, perceptive and penetrating questions, which I noticed set several of the speakers to thinking deeply about how to answer.

Thank you to Conference Solutions, Greg Vickers and his team, for providing their usual excellent service.

Thank you to the Keynote listeners. The notes and minutes of the conference depend very much on your summaries.

We have had very very generous sponsorship, not only from some of the corporations around town and nationally, but also from individuals who have helped scholars get here. As our Chair John Anderson said at the start of today, we couldn't run this conference without your contributions. Thank you.

Finally, a large thank you to our team, led by Cathy Reade who is the driving force behind this conference. We owe a great deal to her brilliant organisational skills, and to her helpers: Larissa Marlow, Sue Faulkner and Lilian Mellink.

Dr Colin Chartres has had a long and successful career in the private sector, academia and government roles. Before joining the Crawford Fund in 2014 he was Director General of the International Water Management Institute (IWMI), a CGIAR Research Centre, headquartered in Colombo, Sri Lanka, from 2007–2012. Previously, he was Chief Science Adviser to the National Water Commission, and held senior management roles in the Bureau of Rural Sciences and Geoscience Australia. He worked with CSIRO Division of Soils from 1984 to 1997 where he focused *inter alia* on soil acidity, soil structure and salinity issues and their impacts on agriculture, and from 2002 to 2004 in the Land and Water Division where he was involved in business development and international science linkages. Colin has a strong interest in the key nexus between science and policy and, through his work with IWMI, specialist interest in water scarcity and its impact on global food security and on science leadership and management best practice. Colin currently Chairs the Expert Review Panel for the Australian Water Partnership, is an Honorary Professor in the Crawford School of Public Policy at ANU, and is a member of the International Steering Committee of the Water for Food – Daugherty Global Institute at the University of Nebraska.

Keynote Listeners' report

Dr Madaline Healey & Rebecca Cotton
Researchers in Agriculture for International Development (RAID)

Introduction

Sir John Beddington's prediction of a perfect storm, a decade ago, set the theme for this year's Crawford Fund Conference. Fittingly, the Sir John Crawford Memorial address was presented by **Professor Ross Garnaut AC**, a former student, and colleague of Sir John Crawford, who spoke of Australia's global role as the engine room of the low-carbon world economy. He highlighted the challenge of adapting to weakly mitigated climate change. In order to reduce the weight of our global footprint we need coordinated and context-specific policy development and science innovation. His address was the underpinning of the conference, with the speakers all united in the message that without significant change a global climate disaster will be upon us.

Professor Sir Charles Godfray, in his morning keynote asked, 'Is the perfect storm still on track to happen?'. And the answer was 'Yes', but he was more positive about our ability to make changes to address the third wave of Malthusian pessimism. The coming challenges – growing demand, hunger and over- and under-nutrition, agricultural pressure and water scarcity – will see more frequent climate and geopolitical shocks. Which led him to ask, 'What if we ate healthily and adhered to planetary resource boundaries to feed the increasing global population? What would the outcome be?'. Ultimately, we would see reduced nutrition-related deaths, reduced greenhouse gas emissions, and increased economic benefits, but to do so we need to look at the effects of both our food production systems and our food consumption patterns. Sir Charles stressed that there needs to be another Green Revolution that takes into consideration the environment in its delivery to avoid a global crisis. Our mid-term food security goals need to be achieved at a pace that has never been seen before to feed the world without destroying the environment.

Weathering and halting the perfect storm: food system solutions

The theme of transforming food production systems was continued by **Dr Bruce Campbell**, who addressed the mega food challenges faced by the global community. He stated that farming as we know it will not be feasible under the current system. Climate change is already with us, and this reality was made clear when Dr Campbell highlighted that we only have 11 growing seasons left to reach our Sustainable Development Goals by 2030. Current agricultural technologies can only take us part of the way to achieving our goals, so we need to scale up climate innovation, adoption, and change, particularly to the 500 million global smallholder farmers.

This is a written report by the 2019 'RAID Keynote Listeners', summarising key messages from the conference. The RAID Listeners are part of the Crawford Fund's RAID program (Researchers in Agriculture for International Development) – a network of early- to mid-career researchers with an interest in agriculture and international development.

Through climate-smart villages (CSV), **Professor Alice J. Ferrer** provided examples of how climate-smart agriculture is being integrated into existing farming systems to transform smallholder farming food systems. By generating best practice evidence, CSV are seeing change at the local and national scale. This provides evidence for policy-makers at the local and global levels to act.

The use of policy to enable change was discussed by **Dr Di Mayberry** in the context of considering multiple dimensions of red meat production to reduce greenhouse gas (GHG) emissions. In the Australian landscape, emissions can be reduced through whole farm system approaches in feed, vaccines and energy inputs and improved efficiency of production and land management. In the developing context, millions of smallholders rely on livestock for food, income, and labour, and she stressed that such changes need to be context-specific. Dr Mayberry also echoed Dr Campbell's thoughts that there need to be GHG reductions in all farming sectors to achieve our goals.

Crops, drops and the climate challenge: configuring the perfect storm

The impact of climate change on agriculture is complex, and in reference to Sir Charles Godfray's keynote **Dr Ajay Mathur** stated that we do not have many options as we move into the third Malthusian wave. Enhancing farm efficiency will be the central solution. Dr Mathur talked us through configuring the perfect sustainability storm to maintain our climate at a 2°C rise scenario. This would entail enhancing water, energy and fuel efficiency; developing the technology to move toward electrification; and addressing the cost and most importantly the adoption at scale by farmers.

Expanding on the concept of farmer incentives for adoption, **Dr Jim Woodhill** highlighted the need for cross-institutional dialogue to make transformational changes in farming systems.

In his case study on the Lower Mekong Basin, **Dr Oudom Phonekhampheng** gave an example of finding solutions for fish passage under infrastructure development in the Mekong, and the interaction between scientific research, engineering innovations and people to create change was emphasised. Neighbouring countries are now looking to adopt Lao research findings in relation to dam design.

It was evident from these talks that by breaking down silos in the context of policy, institutions, countries and regions, there is a strategic global approach for transformation that can be implemented.

Circular food systems and solutions: addressing the nexus issues

Dr Aditi Mukherji spoke on addressing these nexus challenges in South Asia. She called us to think globally whilst acting locally. She described the drastic effects of global warming in the mountains and glaciers of northern India and their implications for water availability and management. She highlighted two major studies. The first on the melting of glaciers and the effect this has on downstream communities. The second on groundwater over-exploitation and unsustainable tapping. These two studies highlighted the challenges faced by

The conference audience in the Great Hall of Parliament House, Canberra, during the Crawford Fund's 2019 Annual Conference.

communities as temperatures increase, particularly at higher elevations where increases are occurring at an accelerated rate.

Dr Mukherji's address was followed by a supporting case study, demonstrating how nexus issues are being addressed. **Marc Noyce** from Biofilta, a private company, outlined how they are supporting the growth of urban farming under space constraints. The company is now working towards translating the success of a low-cost low-tech urban farming system in Australia, to Tuvalu. This implementation of climate resilient food growing systems in the form of raised garden beds unravelled three main challenges for island food production: the lack of top soil, water access issues, and compost production.

Unfortunately, technical difficulties prevented a video link that would have allowed Dr Ângela Manjichi, in Mozambique, to address the conference.

Climate change risk through a finance and liability lens

Ms Sarah Barker, the afternoon keynote speaker, gave an alternative perspective on this complex nexus. Ms Barker spoke about climate change from an economic liability position, and made it clear that business has already taken climate change into account. She stated that climate change is already here; we can't plan for climate change risk, as it is already happening. She identified the power of the stakeholders, their values and their changing perceptions. Ms Barker concluded by stating that leadership in this nexus issue needs to come from business, communities and individuals, with the hope that the government will support with policy.

During the final panel Q&A of the day, **Sir Charles Godfray** explained that we are moving into a world where past data doesn't really tell us a lot about the future. This statement was followed by comments from **Sarah Barker** that companies are looking at their risks and mitigating them before their governments.

Final thoughts

Professor Timothy Reeves provided a succinct conference synthesis reinforcing that the greatest challenge for us in the coming decades is food security. However, he deduced that the overriding message is one of optimism, but not

with business as usual. He concluded by reminding us that sustainability is a moving target, that there is a need for policy cohesion and decisions cannot be made in isolation. Professor Reeves left us with one final thought: we usually say 'produce more for less'; perhaps we should change this to 'produce enough for less'.

Dr Colin Chartres gave the closing remarks, stating that this is probably the biggest challenge we are going to face in the next 20–30 years. If we are going to solve this, we need to do it together.

Madaline Healey is a member of the RAID Networking Executive, a Crawford Fund mentor in Laos and a former Crawford Fund conference scholar. She studied a Bachelor of Agricultural Science at Melbourne University and a PhD in thrips ecology at CQU before heading off to Laos as a volunteer and then mentor in our plant pathology and mentoring activities there. On returning to Australia in 2015, Madaline started working at the University of the Sunshine Coast on ACIAR projects in Laos, Cambodia, Thailand and Vietnam. Her interests are integrated pest management, biological control and all things veggies.

Rebecca Cotton was a Crawford Fund conference scholar from the University of the Sunshine Coast in 2016 and went on to be a Graduate Research Officer at ACIAR based in Canberra and an active RAID member. Bec's B.Sc. majored in sustainability. She then completed her Honours thesis on improving agricultural extension based in Fiji and the Cook Islands, with three months in the Islands conducting research with the subsistence and smallholder farmers.

Conference delegates 2019

*Conference scholars are marked with an asterisk

Abbott, Lynette	The Crawford Fund WA
Akbari, Mona	Department of Agriculture
Akmal, Nadeem	University of Canberra
Alders, Robyn	The Crawford Fund NSW
Allami, Monica	Department of Agriculture
Amatoury, Samuel	Western Sydney University
Anderson AO, John	The Crawford Fund Board, Chair
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Anderson, Kym	ACIAR
Andrew, Neil	Murray-Darling Basin Authority
Angus, Dianne	GRDC Board
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Armitage, Chris	Global Evergreening Alliance
Armstrong, Tristan	DFAT
*Armstrong, Paul	NT Department of Primary Industry & Resources
Arnold AO, Lynn	The Crawford Fund Board
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Atkin, Owen	The Australian National University
*Azman Halimi, Razlin	Southern Cross University
Bacic, Tony	La Trobe Institute for Agriculture and Food
Badaoui, Celine	The University of Sydney
Baig, Irfan	Muhammad Nawaz Shareef University of Agriculture, Multan
Bailey, Joshua	Tasmanian Institute of Agriculture
Balino, Alan	Department of Agriculture
Banyard, Michael	Australian Veterinary Conservation Biology
Barker, Sarah	MinterEllison
Barlow, Snow	The University of Melbourne
Basford, Kaye	The Crawford Fund Board
Beavis, Fern	Australian Academy of Technology & Engineering
Beer, Michael	AgriFutures Australia
Bennett, Sarita	The Crawford Fund WA
*Best, Nickala	La Trobe University
Bird, Lachlan	Bayer
Bishop, Joshua	WWF-Australia
Blackburn, John	Institute for Integrated Economic Research – Australia

Blackburn, Elizabeth	University of California San Francisco
Blanchard, Chris	GRDC Board
Borthwick, Lisa	ACIAR
Borthwick, Octavia	DFAT
Borzyck, Anne	Institute for Integrated Economic Research – Australia
Boustead, Rebecca	Kellogg's
Boutin, Trinity	The University of Sydney
Brassil, Semih	Western Sydney University
*Bridge, Zoe	University of the Sunshine Coast
Broad, Lucy	GRDC
Brown, Lucy	Australian Volunteers Program
*Bryson, Emily	Central Queensland University
Bun, Mara	Food Agility CRC
Burgess, Lester	The Crawford Fund NSW
Bush, Russell	The University of Sydney
Campbell, Bruce	CCAFS, CGIAR
Campbel, Alex	The Crawford Fund Board
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Campbell, Andrew	ACIAR
Campbell-Ross, Harry	ACIAR
Campion, Jessica	Western Sydney University
Cape, Patrick	ACIAR
Carberry, Peter	ICRISAT
Carter, Chris	University of Tasmania – Institute for Marine and Antarctic Studies
Chan, Natalie	The University of Sydney
Chapple, Veneta	Australian Meat Processor Corporation
Chartres, Colin	The Crawford Fund
Chen, Ian	The University of Sydney
Chen, Renee	The University of Sydney
Chikankheni, Jonathan	The Australian National University
Chinniah, Ari	The University of Sydney
Claessens, Michael	Regional Development Australia ACT
Clonan, Maddison	RAID Network
Coffey, Shaun	The Crawford Fund
Consul Goncalves, Charmaine	World Vision Australia
*Cooper, Lucy	University of Tasmania
Cornish, Lisa	Devex

Cosier, Joshua	Western Sydney University
Cotton, Rebecca	ACIAR
*Cox, Jordan	The Australian National University
Crase, Lin	University of South Australia
Curry, Michelle	The FDC Group
Dalton, John	The Crawford Fund NSW
Das, Bianca	RAID Network
Davey, Kirsten	ACIAR
Davidson, Dianne	The Crawford Fund SA
Davila, Frederico	Institute for Sustainable Futures, University of Technology Sydney
Day, Jacqui	Plant & Food Research
*De Bondi, Natasha	Gardiner Foundation
Dean, Eleanor	ACIAR
Delforce, Julie	DFAT
Denning, Glenn	Columbia University
Devoe, Nora	ACIAR
Dibley, Kathy	The Crawford Fund ACT
Dielen, Anne-Sophie	CropLife Australia
*Dieters, Luke	The University of Queensland
Dilanchian, Ani	The University of Sydney
*Diplock, Naomi	AVP volunteer, National Mushroom Centre Bhutan
Dirckze, Dominic	The University of Sydney
Dixon, John	The University of Queensland
Doerflinger, Fran	Plant & Food Research
Dougherty, Liam	The University of Sydney
Drak, Anna	The University of Sydney
Dulhunty, Lauren	The University of Sydney
*Dyussembayev, Kazbek	Griffith University
*Earp, Francesca	The University of Sydney
Eddington, Margie	DFAT
Edgar, Robert	The Crawford Fund Victoria
Emerson, Craig	The Crawford Fund Board
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Essam, Scott	Western Sydney University
Etherington, Dan	Niulife Foundation
Etherington, Richard	Kokonut Pacific Pty Ltd
Fang, Felix	The University of Sydney

Farrell, Laura	Department of Agriculture
*Faulds, Riley	The University of Western Australia
Faulkner, Sue	The Crawford Fund
Fazakerley, John	The University Of Melbourne
Ferrer, Joan	University of the Philippines
Fieldhouse, Robin	The Australian National University
Finfer, Benjamin	The University of Sydney
Fischer, Tony	The Crawford Fund ACT
Ford, Chris	The University of Adelaide
Fox, Paul	Global Edge Projects
Fraser, Greg	Plant Health Australia
Furbank, Bob	The Australian National University
Gale, David	The Crawford Fund ACT
Gale, Garry	Food Agility CRC
Garland, Juliet	The University of Sydney
Garnaut AC, Ross	The University of Melbourne
Garnett, Helen	GRDC Board
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Gaynor, Suzie	ACIAR
Gebbels, Joe	Meat & Livestock Australia
Gerber, Priscilla	University of New England
*Ginty, Josephine	Gardiner Foundation
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Grace, Peter	Queensland University of Technology
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Hanks, Jenny	ACIAR
Haq, Ul Tanveer	Muhammad Nawaz Shareef University of Agriculture, Multan
Hartley, John	Future Directions International
Harvey, John	AgriFutures Australia

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Healey, Madaline	University of the Sunshine Coast
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Hetherington, Jack	ACIAR
Heymanson, Nina	Department of Agriculture
*Hickey, Madi	Animal Health Australia
Higgins, TJ	The Crawford Fund ACT
Hinds, Lyn	The Crawford Fund ACT
Ho, Thu Lan	Department of Agriculture
Horne, Peter	ACIAR
Hossen, Mohammad	University of South Australia
Hou, Evelyn	The University of Sydney
Howley, Carmel	AgResearch Ltd
*Humphrey, John	RMIT
*Humphrys, Meg	NT Department of Primary Industry & Resources
Hussain, Iftikhar	Society of Facilitators and Trainers (SOFT)
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Irwin, Robert	The University of Sydney
*Isu, Faruq Shahriar	University of Tasmania
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Jain, Suzi	Western Sydney University, Kingswood Campus
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Johnstone, Phil	Plant & Food Research
Kabira, Isaiya	Kenya High Commission
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Kotir, Julius	CSIRO
Kretzschmar, Tobias	Southern Cross University
*Krishnan, Vithya	The University of Queensland
Lambert, Georgia	Western Sydney University

Lamberton, Emily	ACIAR
Lashari, Bakhshal	Mehran University of Engineering and Technology
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Lemerle, Deirdre	The Crawford Fund NSW
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Lindberg, Rebecca	Deakin University
Liu, Johnson	The University of Sydney
Liu, Guantong	The University of Sydney
Lopez Marroquin, Patricia	Timothy G. Reeves and Associates Pty Ltd
Lountain, Sophie	University of South Australia
Lovett, John	Australian Plant Biosecurity Science Foundation
Lynch, Ally	Australian Volunteers Program
Lynn, Fiona	DFAT
MacFadyen, Sarina	ACIAR
*Mackenzie, Amy	CSIRO Agriculture & Food
*Mackintosh, Anna	University of Tasmania
Maclean, Jessie	GRDC
Macphillamy, Isabel	The University of Sydney
Man, Neptune	The University of Sydney
Manero Ruiz, Ana	RAID Network
Manjichi, Angela	Instituto Superior Politécnico de Manica
Manteit, Joe	DFAT
Mao, Mao	The University of Sydney
Marbun, Saiful	Department of Agriculture
Mason-D'Croz, Daniel	CSIRO
Mathur, Ajay	The Energy Resources Institute
Mayberry, Di	CSIRO
McBride, Rebecca	ACIAR
McCawley, Peter	The Crawford Fund ACT
McCormack, Miriam	ACIAR
McElligott, April	The University of Sydney
McEvilly, Gerard	Aik Saath
McGill, David	The Crawford Fund Victoria
McKenzie, Tara	ACIAR

*Medina, Daniela	University of the Sunshine Coast
Mellink, Lilian	The Crawford Fund
Memon, Fozia	Society of Facilitators and Trainers (SOFT)
Mendham, Neville	The Crawford Fund Tasmania
Menke, Carl	ACIAR
Milligan, Ann	ENRiT: Environment & Natural Resources in Text
*Milroy, Anita	Central Queensland University
Miskelly, Shannon	ACIAR
*Mitchell, Angus	The University of Sydney
Mohammed, Caroline	Tasmanian Institute of Agriculture
Molesworth, Anika	The Crawford Fund NSW
*Morris, Hayden	The University of Queensland
Morse-Evans, Harry	The University of Sydney
*Moss, Wesley	The University of Western Australia
Mukherji, Aditi	International Water Management Institute
Mullot, Larissa	The Crawford Fund
Neal, Marian	Australian Water Partnership
Neilsen, James	Bayer
Nelson, Madeleine	The University of Sydney
Nevison, Matthew	The University of Sydney
Newman, Suzie	Plant & Food Research
*Nguyen, Duc	Centre for Global Food and Resources, The University of Adelaide
Nguyen, Dao	The University of Sydney
Ninnes, Peter	
Noble, Thomas	QUT
*Noble, Lucy	The University of Sydney
Norman, Phillip	The Crawford Fund Queensland
Noyce, Marc	Biofilta Pty Ltd
*Ocana Gallegos, Cristina	QAAFI, The University of Queensland
Okello, Anna	ACIAR
*Owen, Rebecca	Graham Centre
Pahlman, Christine	ACIAR
Palmer, Jeda	CSIRO
*Pandey, Sunita	Graham Centre
Parish, Campbell	The University of Sydney
Paterson, Mark	Currie Communications
Patil, Raj	Department of Agriculture
Paul, Tania	The Crawford Fund NT

*Peersman, Kai	University of Tasmania
Pepperall, Yolande	Clean Energy Finance Corporation
Peressini, Tamaya	ACIAR
*Phan, Jana	Australian Academy of Science
*Philp, Joshua	The University of Adelaide
Phonekhampheng, Oudom	National University of Laos
*Plowman, Yolanda	The University of Sydney
Pogson, Barry	ARC Centre of Excellence for Plant Energy Biology
Powles, Stephen	GRDC Board
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Pu, Hong	Department of Agriculture
Punthakey, Jay	Groundwater and Environment – Ecoseal
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Robinson, Michael	Australian Plant Biosecurity Science Foundation
San, Kimhour	The University of Sydney
Sanderson, Todd	ACIAR
Sargeant, Rowan	The University of Sydney
*Sarker, Md Abdur	University of New England
Schipp, Mark	Department of Agriculture
Schwager, Joseph	The University of Sydney
Scott, Amanda	Southern Cross University
Scott-Orr, Helen	The Crawford Fund NSW
Sewell, Lauren	Department of Agriculture
Shaw, Tom	The University of Sydney
Sheldrake AM, Richard	The Crawford Fund Board
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*Singh, Sohraab	The University of Queensland
Sinn, Michelle	The Crawford Fund Queensland
Siyal, Altaf Ali	Mehran University of Engineering and Technology

Skelton, Candice	ACIAR
Sombilla, Mercedita	National Economic and Development Authority, Philippines
Spurr, Nicholas	Western Sydney University
Starick, Sharon	GRDC Board
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*Stockwell, Peta	The University of Queensland
Stone, Sally	CAB International
*Suleski, Isabella	The University of Western Australia
Sun, Michelle	The University of Sydney
Tan, Hui Tsien	The University of Sydney
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Tatnell, Andrew	The Crawford Fund
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*Taylor, Emma	Faculty of Veterinary & Agricultural Sciences, The University of Melbourne
*Thepot, Valentin	University of the Sunshine Coast
Thompson, Malcolm	Department of Agriculture
Thorp, Grant	Plant & Food Research Australia
Tilleard, Simon	Australian Water Partnership
*Timilsina, Sanjaya	Central Queensland University
Tinning, Chris	DFAT
Tobin, Travis	Queensland Farmers' Federation
*Tran, Lily	La Trobe University
Tran, Sonia	The University of Sydney
Truelove, Wendy	Western Sydney University
Umberger, Wendy	The Centre for Global Food and Resources, The University of Adelaide
Van Doorn, Shanlee	Western Sydney University
Van Heaften, Shanice	RAID Network
Walker, Daniel	ACIAR
Walker, Stacey	DFAT
Wallwork, Hugh	The Crawford Fund SA
Wang, Derek	The University of Sydney
Wang, King	The University of Sydney
Warner, Richard	The Crawford Fund Board
Watson, Guy	Global Edge Fifth Pty Ltd
Webb, Michael	The Crawford Fund Queensland
Webber, Rhys	The University of Sydney
Weir, Glen	The Crawford Fund SA

*Wells, Duncan	Curtin University
Wheeler, Sarah	The Centre for Global Food and Resources, The University of Adelaide
White, Barney	The University of Sydney
*Wichmann, Antoinette	The University of Melbourne
Williams, Rachel	Western Sydney University
Williams, Amy	GRDC
Williams, Peter	Earth Exploration
Windsor, Peter	The University of Sydney
Wollenberg, Lini	CCAFS, CGIAR
Wong, Karina	The University of Sydney
Wood, Mellissa	ACIAR
Woodhill, Jim	University of Oxford
*Woodiwiss, Olivia	University of Tasmania
Woodman, James	Department of Agriculture
Woods, John	GRDC Board
Wynn, Peter	The Crawford Fund NSW
Xu, Chelsey	The University of Sydney
Yang, Ying	School of Agriculture, Food & Wine, The University of Adelaide
Yargop, Rohan	The Crawford Fund SA
Young, Molly	The University of Sydney
Zalcman, Emma	ACIAR
Zhang, Kevin	The University of Sydney

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For further information,
to support us or to be kept informed
of the Crawford Fund's work, please contact:

THE CRAWFORD FUND
Building 7, Unit 7, 1 Dairy Road
Fyshwick ACT 2609 Australia

Phone: 02 6280 8611
Email: crawford@crawfordfund.org

www.crawfordfund.org

ABN: 86 141 714 490

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