KEYNOTE ADDRESS

The scramble for natural resources: How can science help?

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Abstract

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

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

The scramble

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

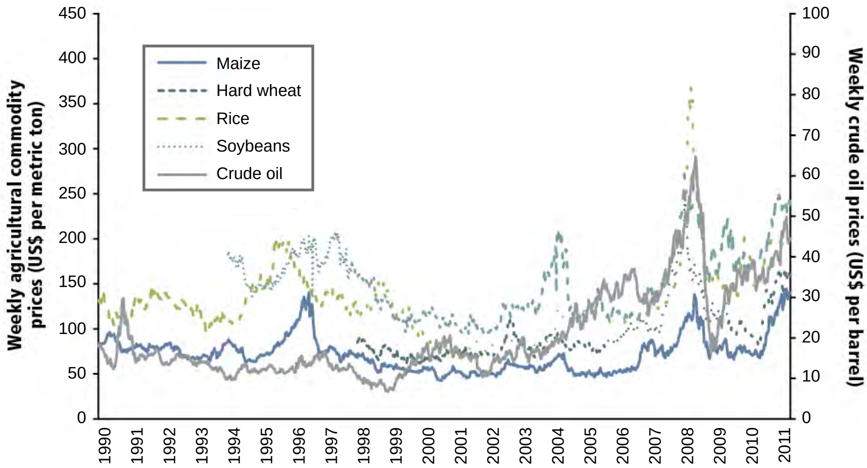

Figure 1. Spikes in food and oil costs: inflation-adjusted prices of maize, wheat, rice, soybeans and oil, 1990–2011, in US dollars per tonne of food (left) and per barrel of oil (right). Source: IFPRI.

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

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

The Green Revolution

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

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

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

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

Humanity's greatest challenge

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

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

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

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

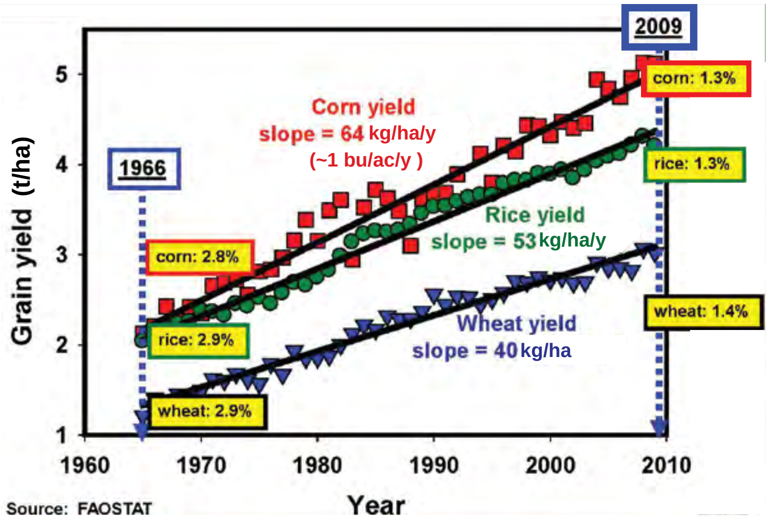

Figure 2. Global cereal yield trends, 1966–2009.

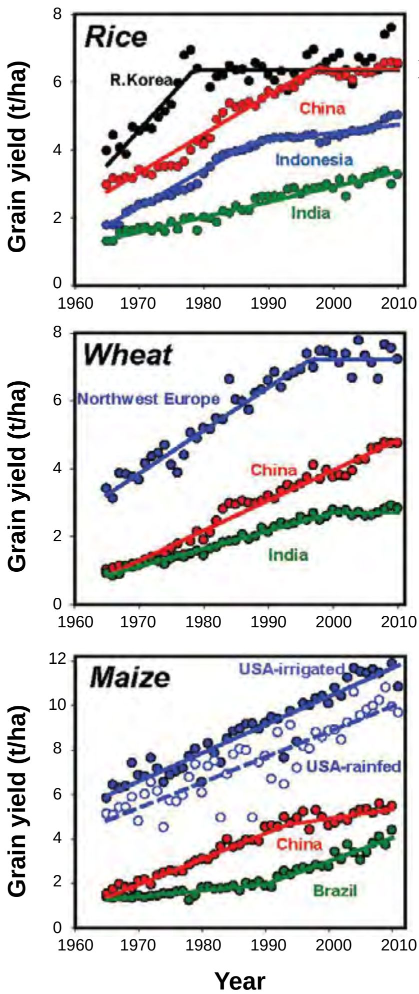

Figure 3. Plateaus in yields of major grains.

Is it possible?

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

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

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

Improving productivity

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

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

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

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

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

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

What is the potential?

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

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

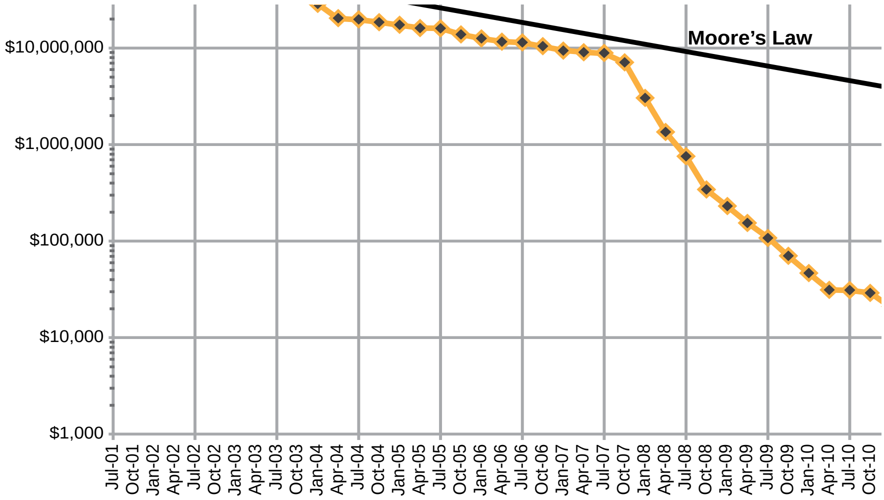

Figure 4. The cost per genome in DNA sequencing (yellow line) is falling faster than Moore's Law's projections of the cost of making computer chips.

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

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

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

The CGIAR reform process

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

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

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

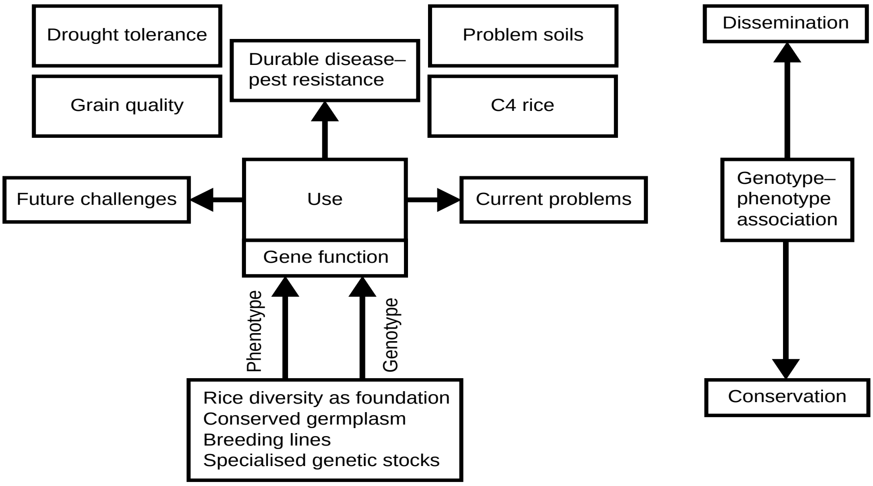

Figure 5. The genetic diversity research platform in CGIAR.

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

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

CGIAR research agenda

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

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

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

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

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

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

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

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

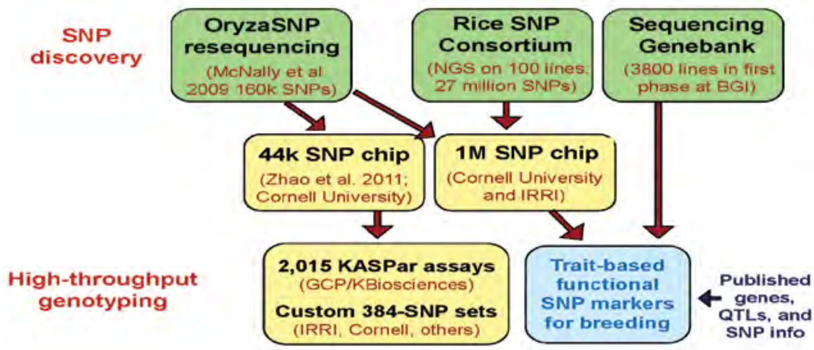

Figure 6. CGIAR has new resources for gene discovery.

The CGIAR genetic diversity treasure-chest.

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

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

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

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

Benefits to Australia

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


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

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

Impact of CGIAR research

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

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

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

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

Conclusion

Yes, the food price spikes in recent years have led to a scramble for natural resources, such as land grabs in Africa, but they have also put food security back at the top of the agenda. Science can help the world grow more food using less land and less water, thereby limiting humans' natural resources footprint. CGIAR has a promising agenda that harnesses the potential of science to feed the world's growing population. It is pleasing that this work also benefits Australia, which is a valued and strong supporter of international research and agriculture through ACIAR and AusAID.

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

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