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Facing the uncomfortable challenge of food security

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Svalbard Global 'doomsday' Seed Vault

Abstract

Today agriculture faces threats that are arguably more daunting than in any previous era. The basic components of food production – land, water, nutrients, climate and crops – all appear poised to undermine rather than improve food security and thus threaten national security and peace. This address enumerated the impediments to crop production and posed the question of whether we are prepared to help crops adapt and flourish in these changed conditions. Dr Fowler concluded with a virtual tour of the Svalbard Global Seed Vault – a notable effort to fashion a long-term solution to the loss of the genetic diversity upon which agriculture will depend in the future.

Deep in our hearts we all know and agree on three important things about food security and the future. The first is that we're going to need to produce much more food in the future, something like 50 to 70 per cent more. The second is that we're probably not going to do that in the same way that we've done it in the past. There are limits to the amount of land, water, energy and resources that can be devoted to agriculture. So pick your timeframe – 10 years, 20 years, 50 years, 100 years – but you'll agree that at some point in the future agriculture is going to change in probably some fairly fundamental ways. The third thing we know is that we're not acting as if we actually believe the first two things.

In an impressive book published some years ago called *Feeding the Ten Billion,* the Australian crop physiologist Lloyd Evans laid out the six possible ways food supplies can be increased:

1. Increase the amount of land under cultivation
2. Increase the yield per unit of land
3. Increase the number of crops grown per year
4. Replace lower yielding crops with higher yielding ones
5. Reduce post-harvest losses
6. Decrease the use of feed going to animals

Until the mid-1980s the dominant factor in increasing food production was expanding cropland. As population increased, people cut down trees, cleared land and produced more cropland and therefore more food. But in the mid-1980s something quite dramatic and historical happened. For the first time since the dawn of agriculture, the greatest portion of the additional food being produced came from intensifying agricultural production. It was not generated by increasing the amount of cropland.

Ways we could increase production

Moving forward there are many things that we could do to increase production. We could all become vegetarians for instance. That would address number six on Evans' list. It would make much more food available. But, how likely is this to happen and how quickly? I think that you have to agree that number two – increasing productivity – is really going to be the crux of the issue moving forward. This is where we really must make serious progress. Yes, there will be more crop land in the future, the estimates are perhaps five per cent more by mid-century, but number two is really where the heart of the matter rests. And yet there are some significant obstacles to producing more food through intensification of agriculture. I will briefly outline some of those obstacles.

The first is water; I don't really need to talk much about that in Australia. Agriculture takes 70 per cent of fresh water supplies around the world, 80 per cent in the United States. Do you know that so much water is stored behind dams and in reservoirs in the world that this weight has added a measurable wobble to the spin of the earth according to NASA? And yet that's not enough water for our needs. There are 37 major aquifers in the world, 21 of which are in decline; 13 of which are in serious decline where there is little to no replenishment. The aquifer in the Mid East, the Arabian aquifer, is probably the worst of all. You can imagine what that portends for the future. The overdraft is some 50 per cent in parts of India, 25 per cent in China and yet even this dramatically unsustainable rate of depletion is not enough to meet demand.

Looking forward we're anticipating a 400 per cent increase in need for water for industry. The International Water Management Institute, one of the Consultative Group on International Agricultural research (CGIAR) institutes, is estimating that by mid-century the demand for water in agriculture will double. That's quite interesting, since we're already using 70 per cent of total fresh water supplies. Obviously something has to give.

If you consider nutrients, fertiliser use in this world is up 23 times since I was born. We know that there is likely to be peak phosphorus production in this century, perhaps even as early as mid-century.

Turning to climate, we face even more challenges
I realise some people in this country and others don't believe in climate change. In my opinion the scientific evidence for climate change is absolutely overwhelming. But whether what we are experiencing is climate change, or natural fluctuation, or just coincidence, the truth on the ground is that farmers are experiencing a lot of bad weather. This past June was the hottest June in recorded history, both for land temperatures and ocean temperatures. It was about 1.25˚C higher than the 20th century average. At 2.0˚C many of our crops will enter uncharted territory in terms of climate. But June was no anomaly; it was the 364th consecutive month in which the temperature was greater than the average temperature for that month for the 20th century. That's a lot of coincidence, 364 consecutive months of higher temperatures than the 20th century. In the future, the coolest and best growing seasons are going to be hotter than the hottest of the past according to current accepted climate projections. The best growing seasons of the future will be worse than the worst of the past. The thought is humbling.

What does excessive heat do? It affects all plant parts and all plant processes. It alters the life cycle. And of course at a certain point it begins to reduce yield, quite dramatically. But heat comes in many guises and there is no single crop gene for heat tolerance or climate change. So what is it that plants are going to have to adapt to? They will have to adapt to higher average temperatures, higher extremes, longer periods of very extreme temperatures, higher minimum temperatures, and higher night time temperatures. They're going to have to adapt to hot weather during very inconvenient times for the plant such as flowering. And they will need to adapt to more temperature fluctuations.

There is another thing to which crops must adapt, something that's rarely mentioned. With climate change you get migration, changes in the natural range of insects, pests, pollinators, all kinds of living things. As a result, our crops will be growing amongst new combinations of species.

In summary, there will be dramatic new combinations of temperatures and precipitation, and new and novel assemblages of species for which there are no historic analogues in agriculture. Moreover, from an evolutionary and agricultural perspective, these changes are coming very rapidly.

Two messages emerge from the foregoing. The first is that these developments are going to create added uncertainty, surprises, and heightened risk in our production systems. This is going to be manifested, I predict, in market disruptions, in higher food prices, in food export bans and in political upheaval and civil strife. And of course it will lead to greater food insecurity for the people who are already food insecure.

The second message is that we cannot expect our crops to come pre-adapted to climates and environments that have never before existed.

What do we know about adaptation?

We learned a considerable amount about adaptation in 1859 with the publication of *On the Origin of Species* by Charles Darwin. Darwin argued that the combination of variability, inheritance, natural selection and time explains adaptation and evolution. Darwin spoke about natural selection daily and hourly, closely scrutinising variability. Fortunately we still have genetic variability in our conserved crop genepools. There's no more valuable natural resource on earth, and there's no resource upon which people across the globe are more interdependent.

In the mid-1990s, I was recruited by the Food and Agriculture Organisation of the U.N. to move to Rome and head a team to make the first global assessment of the state of the world's plant genetic resources for food and agriculture. Part of the concern at that time was that we had lost, and were continuing to lose, crop diversity.

What I found working at the U.N., looking at the state of plant genetic resources, was that we had a number of good genebank collections around the world. There are people in this room responsible for the new genebank in Horsham, Victoria, and I think you should give them a hand because it is a fantastic facility and operation!

More often than not, particularly in developing countries, I found that the genebanks were sub-standard. The materials in them were poorly housed and rather often poorly managed. None of the genebanks in the world had a secure multi-year budget and more than a few of these genebanks had become hospices and I'm sorry to say that a few were even like morgues. My mentor in this field, Jack Harlan, cautioned that if you're willing to trust the fate of mankind on these collections you're living in a fool's paradise!

So the question is: if we have this great new genebank in Horsham, why should we care about the others? In my country, the United States, we have a fabulous national genebank. Should we care if there's another country that has a genebank in disrepair? There are really two reasons to be concerned.

The first is that we're all interdependent and our genebanks and our plant breeding programs are interdependent. So you might think that a country like the United States with a gigantic and very important wheat industry would have a huge collection of wheat samples – and it does, it has five per cent of the genebank samples of the entire world. Australia has three per cent. So looking forward, if a country like the United States is content to say that it has all the traits it will need within the five per cent of the global samples it manages, fine. But my guess is that most plant breeders would say that the other 95 per cent could be interesting – even critical!

The second reason is that all genebanks are vulnerable. For instance, a fire went through the Philippine National Genebank and destroyed part of that genebank – the part that had not been damaged by the typhoon that came through a couple of years before that.

In a sense we are our brother's keeper. If you think about these resources as being important, if you think about all the countries of the world being interdependent, and you consider the fact that all of these facilities are in buildings, that they're subject to natural disasters, they're subject to equipment failures, human error and budget cuts as well as natural disasters, fires and civil strife, then you will realise how very vulnerable this 'systems' crop diversity is and how vulnerable, therefore, our agricultural system might be.

About ten years ago a couple of us got together and decided that enough was enough, because we'd had enough of seeing this diversity become extinct through human errors and budget cuts and civil war, and we decided to try to do someone about it.

The result was the Svalbard Global Seed Vault

Svalbard is very remote. If you're in Rome, Italy, and you fly to Oslo you're almost half way there. It's a long way north. It is a remarkably beautiful place. I know some of you have been there.

Our idea was to build a seed vault that would essentially run by itself with no on-site staff. If you want to conserve seed over the long term, you freeze it. But we didn't want to depend totally on mechanical freezing equipment; we wanted to benefit from the natural freezing offered by Svalbard's permafrost by being about 130 metres inside the mountain. It wasn't an easy facility to build, everything had to be imported and the construction workers had to be strong and tough.

The Global Crop Diversity Trust has been quite active in sourcing the seeds and working with developing countries and working with the CGIAR – and Australia – to move seed samples up there. Seed deposits are made a couple of times a year. Boxes of seeds arrive at the airport in Longyearbyen, Svalbard. They're brought up to the seed vault by a cleverly titled transport company called Pole Position. When you walk through the front door you're looking down a long, gently downward slopping tunnel. This is practical facility, not an antiseptic laboratory situation. At the end of that tunnel you come to an expansive, tall ceilinged room. I think of it as sort of a 'cathedral' room.

There are three seed storage rooms just beyond the large cathedral-like space. One is in use. The largest collection of agricultural biodiversity in the world is stored within this room in the Svalbard Global Seed Vault. It houses and protects seed samples, about 500 seeds per sample, of 864,000 different crop varieties. There are more than 120,000 different varieties (or more properly 'populations') of wheat, more than 120,000 different varieties/populations of rice. There are more than 900 genera represented in this room, more than 5000 species originally sourced from 233 countries (including a number of countries that don't exist anymore).

The conservation in this facility is offered free of charge. Funding needs, which are modest, are secured in perpetuity through an endowment established by the Global Crop Diversity Trust. Norway doesn't claim – in fact it explicitly rejects in a signed contract – any physical or intellectual property rights over the material. Deposited materials can only be returned to the depositor, their owner. They are not accessible to any others, including other depositors.

I cannot claim that nothing could go wrong in this facility. But we tried to anticipate and address as much as possible. We know, for example, that if all the ice in the world melts and the biggest tsunami in history takes place at this location, we'll still about five stories above the water. We also know that the room housing the seeds will remain below the freezing point 200 years from now even in the worst climate change scenario. Something could go wrong, of course, but I'll tell you that when I enter this room I have the feeling that for the first time in history human beings have actually insured the long-term survival of certain species – in this case more than 5000 of them – the species most critical for the future evolution of our agricultural crops.

Addressing institutional risks

Let me now back up and say one or two other things. I serve on the board of trustees of a small liberal-arts college in the United States, Rhodes College. One of the things that we do at the end of every board meeting is close the doors, ask all the staff except the President of the college to leave the room and ask him 'What wakes you up in the middle of the night, what scares you the most as the President of this college?' As a board, it is our duty to be aware of and address institutional risks.

In keeping with this tradition, I want to talk for a couple of minutes about what scares me the most. Yes, I still worry about the fate of crop diversity. The Seed Vault that I dearly love is a wonderful gift from the Norwegian Government to the international community. But it's not enough! We don't need one safe copy of all the biodiversity in the world; we need at least two safe copies. The Global Crop Diversity Trust is the sole formal mechanism in the world for creating a global system and ensuring the long-term conservation and availability of crop diversity. The Crop Trust is trying to build an endowment for this purpose, but it still needs considerable funding to finish the job. So that of course worries me.

Mostly, however, I have to say that I'm worried about crop adaptation to climate change and the assumptions that we're making about this. There's a reasonable, but I think still insufficient, amount of research being devoted to certain major crops – to rice, wheat, maize and soya beans. But I find myself particularly worrying about what I would call the orphan crops, the smaller crops that in many cases are really quite important. I have friends at Stanford University who have published a study of orphan crops. Their work focuses on 27 crops of significance for which there is alarmingly inadequate research commitment globally. These 27 crops occupy some 250 million hectares of cropland in the world – that's about 100 million hectares more than rice, in fact it's more than any of our individual major crops, and about five times the arable land of Australia.

These 27 crops are obviously important but under-developed and under-appreciated contributors to food security. They are crops such as tef in Ethiopia. There are Andean root and tuber crops, crops that you find in developing-country marketplaces. My point in talking about these is that we cannot assume that these crops are simply going to adapt themselves magically to climate change, all across 250 million hectares.

Probably half of the crops in the world that have been domesticated and have entered into world commerce have never had a single Mendelian-trained plant breeder working on them. So we're facing a situation where, for crops occupying currently more than 250 million hectares in this world, we have very few plant breeders and no additional diversity getting out into the field.

An historical precedent

This predicament has actually been faced by societies before, most notably in the United States where early settlers from Europe found a continent that essentially was devoid of the type of agriculture and crops that we have today.

What did the government do? It imported a massive amount of crop diversity throughout the 1800s. There were government programs to acquire, study, multiply and distribute that diversity to farmers in quantities for experimentation, adoption and further selection and development. In the late 1800s, the U.S government mailed out seed packets to farmers for experimentation. In 1898 it sent out 20 million boxes of seeds, each containing multiple packets. One cannot explain the spread and adaptation of crops in the United States without reference to this mass distribution of diversity. So I ask, could this be done again, particularly in developing countries where there are no breeders and the farmers don't have the appropriate kind of diversity to help them adapt their orphan crops to climate change? Could diversity once again be distributed and deployed for the purpose of promoting experimentation and adaptation? Is there a realistic alternative?

This is neither the time nor the place to go into this subject, but I ask you to consider whether providing carefully chosen diversity from genebanks and from breeding programs of these types of 'minor' crops might allow farmers to select and accumulate those variations that would help their crops adapt to climate change. Perhaps you will consider this a crazy, radical experiment. But I will point out that we are now engaged in an even more radical experiment on earth. That experiment is to see if our crops are going to magically and quickly adapt themselves without the aid either of plant breeders or diversity. This is an experiment without historical precedent or scientific basis.

I began this lecture by saying that I thought we could agree on three things: we need to produce more food, agricultural systems are going to change in some substantial ways, and we are behaving as if neither of these things is true. I'm convinced that we're not adequately prepared today for climate change or natural fluctuation or bad weather, or for this month to extend the 30 years' worth of consecutive months of above-average monthly global temperatures. We are not prepared to address this rapidly unfolding crisis, at least for most of our crops.

I acknowledge that conserving plant genetic resources is not a panacea, but I do believe it's a prerequisite, a prerequisite for food security. So I have to sort of shake my head sometimes, realising that I've spent 40 years of my life working on this particular issue and yet we are still struggling with how we are going to fund the genebanks adequately and sustainably. I must say to you that I've never met anyone who said to me: 'Well, Cary we don't really need to fund the genebanks, we don't need to conserve this diversity.' Everybody's in favour of it. But usually what they tell me is: 'This is not a good year for it – you know we've got a recession, we've got unemployment, we've got a war, we've got all kinds of things that we need to do, so this year is not a good year'.

I've been hearing this for 40 consecutive years, so I now know two things for sure: the first is that this year is not a good year. And the second is that next year is not going to be a good year either. In the face of monumental and historic changes in the availability of land, water and other resources, we seem to be pretending that somehow a 'business as usual' approach to food security and food production is going to work. It seems to me that this is short-term thinking, and that short-term thinking has created long-term problems that we're not going to solve by more short-term thinking.

How serious are we about food security and climate change?
Investments in conserving and developing crop diversity will be an early indicator of just how serious human society is about food security and climate change. In the scheme of things, conserving crop diversity, a prerequisite for plant breeding and for food security, is a tiny investment to make that is neither disruptive to our economy nor to our lifestyle. So if we can't make *that* kind of investment, I question whether we're going to make *any* meaningful investments.

I want to spend just one minute talking about political leadership. To political leadership in many countries, agriculture is just a sub-category within the overall economy; it's not a driver of global events. So our agricultural leaders are not our national leaders, and our national leaders are not engaged emotionally, intellectually, politically, in the business of agriculture and food security. Yet the *sine qua non* of leadership is to lead, it's to explain to the public, to one's followers, why difficult things, challenging things, complicated things need to be done. This is the uncomfortable challenge that our leaders face.

Norway has a postage stamp with a picture of the Seed Vault on it. I wish that there were more countries like Norway that had done something so significant and long-term to support food security, that they proudly celebrated it on a postage stamp. We need all countries in the world to have their postage stamp for something that they've done that's significant and important for the rest of the world.

Producing more food sustainably with little if any more land, with less water, with less nutrients, with fewer people, and in the context of climate change – this is not a problem that's confined to the rural areas or one sector of our economy or one government ministry! This is humanity's pre-eminent 21st century challenge. I think that crop diversity has a role to play in meeting that challenge.

Otto Frankel, the eminent CSIRO scientist who Tim Fischer mentioned in the introduction, was one of the founders of the field that I've spent my life working in, and he had three words that he used to describe the relationship, the covenant that we have with our domesticated crops. Reflecting back on the nature of this relationship and on our history, he said that we have ‘acquired evolutionary responsibility’. I can’t think of a better more accurate, more persuasive, powerful and more humbling comment than that; we have ‘acquired evolutionary responsibility’.

I want to end on a personal note. It’s a great honour to be with you today to give this lecture. I think that Australia has, at least on a per-capita basis, provided more leadership to international agricultural development than any country on earth. It may have started with John Crawford but there have been a number of wonderful people that have picked up that baton. I will mention just a few names because I have been blessed in my life to work with and become friends with some of you in the audience – with some Australians that I believe have been exemplary international public servants: Alison McCusker, Tim Reeves, Meryl Williams, Gabrielle Persley, Bob Clements, the Crawford Fund’s own Cathy Reade, and two of my dear friends Tony Gregson and Mellissa Wood. These people have marvellously enriched our global community and they’ve enriched my life. I want to say thank you to all of them, and all of you.

Dr Cary Fowler is best known as the “father” of the Svalbard Global Seed Vault. He headed the international committee for its establishment and he chairs the Council that oversees its operations. The Seed Vault provides ultimate security to more than 864,000 unique crop varieties, the raw material for all future plant breeding and crop improvement efforts.

In 2005 Dr Fowler led the Global Crop Diversity Trust whose mandate was to develop a rational and effective international system for conserving crop diversity, in perpetuity. In the 1990s he led the team to produce the UN’s first global assessment of the State of the World’s Plant Genetic Resources, drafting and negotiating the first FAO Global Plan of Action on the Conservation and Sustainable Utilization of Plant Genetic Resources, which was formally adopted by 150 countries in 1996.

Dr Fowler was a Special Assistant to the Secretary General of the World Food Summit (twice) and represented CGIAR/World Bank in negotiations on the International Treaty on Plant Genetic Resources.

He has served on many boards, including Rhodes College, the NY Botanical Garden Corporation, the U.S. National Plant Genetic Resources Board and the International Maize and Wheat Improvement Center in Mexico. He is the recipient of many prestigious awards and two honorary doctorates. He is a member of the Russian Academy of Agricultural Sciences and Academy of Sciences. He has lectured widely and is the author or co-author of more than 100 articles and several books.