THE CRAWFORD FUND
For a Food Secure World

TRANSFORMING LIVES & LIVELIHOODS

THE DIGITAL REVOLUTION IN AGRICULTURE

The Crawford Fund

2017 ANNUAL CONFERENCE

Parliament House, Canberra ACT, Australia, 7–8 August 2017

Editor: A. Milligan

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

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

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Foreword

The Crawford Fund's annual conference holds a key place in the development and food security calendar in Australia. For more than two decades we have successfully brought into focus each year an issue worthy of global and Australian attention. This year has been no exception.

Titled 'Transforming Lives and Livelihoods: The Digital Revolution in Agriculture', our 2017 annual conference has focused on the current and future likely impact of the data revolution for smallholder farmers.

Big data represents an unprecedented opportunity to find new ways of reducing hunger and poverty, by applying data-driven solutions to ongoing research for development impact. These *Proceedings* now provide an enduring record of the conference presentations, supporting further application of such solutions.

By attracting the world's best speakers, providing extended question and answer sessions and opportunities for informal networking, this year's conference has, as in previous years, enabled participants to contribute and to place food security issues into a context relevant to their lives and work.

Sir John Crawford Memorial Address

As always, our conference started with our popular networking dinner and the Sir John Crawford Memorial Address presented annually since 1985 in honour of the remarkable Australian in whose name the Crawford Fund was established. Sir John Crawford contributed at the highest levels to the development of Australia and other countries, and passionately supported international agricultural research for development.

This year's Sir John Crawford Memorial Address was titled 'A new narrative for ending hunger' and our speaker was Dr Lindiwe Majele Sibanda, an authoritative leader in agriculture, climate change and nutrition.

Dr Sibanda is Vice President for Country Support, Policy, and Delivery at Alliance for a Green Revolution in Africa and a Member of the Policy Advisory Council of the Australian Centre for International Agricultural Research.

Engaging young Australians in food security

The Crawford Fund Scholar Program, and our international travel awards and hosting of Researchers in Agriculture for International Development (RAID), are three aspects of our efforts to encourage young Australians to engage in international research, development and education for the benefit of developing countries and Australia.

Scholarships to attend the Crawford Fund Annual Conference are awarded to young people who have a genuine interest in international agricultural development. The scholars are matched with a mentor for the event and take part in two half-days of activities before and after the conference. Since the program started in 2010, we have had more than 175 scholars. This year's conference alone has brought in almost 50 scholars.

Acknowledging our supporters

The Crawford Fund would like to thank those who supported a scholar or have donated to our efforts this year. The scholars are among the delegates listed at the end of these *Proceedings*, and our scholar supporters are named in the Acknowledgements, along with the conference sponsors and Chairs this year (pp. v–vi immediately preceding this Foreword).

Most of our scholars go on to be part of RAID, which is a wonderful network that brings together early to mid-career researchers working or wanting to work in developing countries. RAID members helped with this year's Scholars' Days (see www.raidaustralia.net), and RAID members have provided a summary of the whole conference, which is included in these *Proceedings* (pp. 133–137).

Conference scholars with the staff and Board of the Crawford Fund, August 2017

2017 SIR JOHN CRAWFORD MEMORIAL ADDRESS

A new narrative for ending hunger

Dr Lindiwe Majele Sibanda

Alliance for a Green Revolution in Africa (AGRA)
& Australian Centre for International Agricultural Research (ACIAR)

Thank you very much, Honourable John Anderson. I'm wearing a bright coat but I suppose one thing that you could not tell and remains a secret until I say so, is that part of my umbilical cord is buried in a log in a rural village in Zimbabwe, just at the doorstep of my grandmother's thatched hut, which has got cow-dung polish. And one of the most exciting debates I've had with my three teenage children recently was that they are better citizens than me because of my rural roots. And being their mother, I managed to win the debate by telling them that parts of their umbilical cords are probably swimming in sewage because they were born in the city, yet I remain connected to agriculture.

My connection with the family smallholding farm and my admiration for my grandmother continue to inspire me in my daily work 37 years after her passing-on at the majestic age of 110 years. She remains my hero.

On her one hectare holding which was carefully divided into the residential part (one acre) and the remaining one acre totally dedicated to farming, she was able to plant a colourful diversity of crops. They turned out into rainbow colours of maize, yellow millet, sweet sorghum, a vegetable patch with red, yellow and green vegetables, and an orchard with large mango trees interspaced with smaller oranges, lemon trees and guavas which we could eat *ad lib*. At the far back end of the homestead there was a kraal which kept our goats that were our source of meat, our two dairy cows for milk and four oxen that provided draught power for our planting seasons.

The chickens were free-ranging, providing eggs for the family. Only rarely, when my dad visited, did we have the luxury of enjoying chicken soup when most of the meat was for him. The commonly eaten meat was goat meat. One slaughter per month was enough to suffice for the whole family, because we dried the meat and just on the first day we would enjoy fresh meat; the rest was dried and it was strictly one small piece each per day.

Grandmother's farm was a source of food but also our pharmacy.

Paper prepared from a transcript of the Sir John Crawford Memorial Address 2017, on video at https://www.crawfordfund.org/news-a-new-narrative-for-ending-hunger-lindiwe-sibanda-presents-2017-sir-john-crawford-memorial-address-august-2017/

She made sure that all her 20 grandchildren worked on the farm. Three times a year we would come from the city for school holidays in the back of a truck, all 20 of us, to provide free labour and enjoy learning and working with my grandmother. The January school holidays was an exciting time, because that would be the time for weeding. Every one of us with our hand hoes would be following behind grandmother, one line at a time, making sure that we carefully weeded and removed all the weeds from the farm. March holidays was an exciting time because that would be the time for top-dressing fertiliser application, just before the harvest. We would walk with a bag of fertiliser, a teaspoon in hand, and apply one teaspoonful at the side of each plant, with grandma watching to make sure there was no wastage. Finally, harvest time, August, the school holidays. We were excited because as we harvested the maize cobs you got a chance to put one in the pocket for an after-hours roast. So that was the agriculture I experienced in Zimbabwe in the '70s.

It was also exciting that when we left the village and went back to the city, grandmother made sure that we took back enough supplies to carry us through the whole of the school term. Unfortunately the reverse is true now. We have to buy food to support our kin in the rural areas.

We were a big family of aunties, uncles, cousins, brothers and sisters, all resident in the same farming homestead. All 20 of us would participate in both the growing of the food and the preparation of the food during meal time. Dinner was the main meal, and always served by my grandmother. The serving portions were carefully measured to avoid waste. They provided sufficient for each age group. There was always one piece of meat per person. My dad of course got more and we know that. My grandmother would say, "Eat just enough so that you leave room for your stomach to breathe". When food was ready we all sat on the cow-dung-polished floor facing her in a half-moon fashion, in a designated group: girls alone, boys on their own, the younger children. The nursing mothers would sit closest to grandmother, with their children on their laps so that she would supervise the feeding and make sure that the children were well fed. It's no surprise therefore that most of my generation that were raised by grandmothers came out to be big Zulu girls and boys, bright students at school and with a well-balanced livelihood. We were well nourished.

I went to college in the '80s to study agriculture. I was lucky to benefit from post-independence benevolent governments that gave Zimbabwe scholarships for us to go and study. Since I'd always wanted to be an airhostess, when I saw my name in the newspaper that I had been awarded the scholarship I didn't think twice: I left the country to go and study. When I got to Egypt, I was given a choice between dentistry and agriculture. I didn't waste a second to think: I followed my passion, mostly because that was the year my grandmother had passed on. So I felt, in respect and in memory of her, this was the right thing to do, much to the surprise, maybe disgust, of my family and my friends, who thought, "Who on earth goes to study farming?". Up to this day I am still asked, "So what is different from the agriculture you learned at school and what your uneducated grandmother used to do?".

Unfortunately and sadly I have very little to show for my continent. What I learnt in college was totally different from what I had seen practised by my grandmother. I learnt that back in the '60s and '70s there was a Green Revolution in Asia. This Green Revolution was able to avert disaster, mass starvation. Unfortunately Africa had not benefited from this Green Revolution. The continent had not benefited from the great technology breakthroughs of the '60s and '70s.

The African continent was left behind for several reasons. The high yielding crops focused on irrigated cereals which were not very suited for our agricultural conditions where there was, and still is, only 10% irrigation coverage. There were failures in infrastructure then and there still are at the moment. And policy challenges made it such that markets were not functional – and they still aren't.

So what else did I learn? I also learnt that through the United Nations Food and Agriculture Organization (FAO) some 30 of the 53 African countries are producing less food per head of the population than they did in the '60s – and it's still a challenge now.

I also learnt the concept of 'food security', which according to the FAO originated in the mid '70s in the discussions of international food problems at a time of the global food crisis. The initial focus then was primarily on food-supply problems – on assuring the availability and, to some degree, the price stability of basic food stuffs at the international and national levels. Food security was defined then through the World Food Summit of 1974 as:

> Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices.

By 1993 when I graduated with a PhD in agriculture there were up to 200 definitions of food security, which to me was a clear demonstration that there are differing views and there is a problem. However, the definition that acquired the broadest acceptance was the FAO definition of the World Food Summit of 1996, and it defined food security as follows:

> Food security exists when all people at all times have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

I underline active and healthy life.

When I graduated with a PhD in Animal Science, I was so sure that the Matabele goats that were dished out by my grandmother at one piece per day would increase in productivity, and I, for one, would afford my family lots of meat every day and it wouldn't be rationed.

When I got home to Zimbabwe, my nephew Moses had taken over the family farm and indeed was practising the FAO agriculture-revolution thinking, of 'more, more, more'. He had cleared the entire farm; he got rid of everything that was not giving him money; the whole one-hectare farm was dedicated to corn. There was no space for produce with no commercial value such as fruits, the vegetables, the millet and the sorghum; they were all gone. The goats had been sold off, one by one, to meet household cash needs and pay school fees

and hospital bills. Income from farming was used to purchase hybrid seed and fertiliser and, most important, to push him up the 'development ladder'. To Moses and many more in the village, development was about getting off the cow-dung-polished floor and buying a bed and a dining room table. It was about buying a television set so that they could enjoy the entertainment in the evenings.

What was strange for me, though, was that the yields of maize that Moses was getting from the farm were dwindling and were close to half of what my grandmother had been getting. In a bid to supplement his income, Moses left the farm to his wife and his two children and he went off to the city to get a job. Three years later he still couldn't get a job and he decided to move from Zimbabwe to South Africa and look for greener pastures. He never got a job.

Now Moses's wife Peggy is left in the village – just like my grandmother who gave us everything she produced, all the food that came from her farm. Moses's family is dependent on the maize that is produced: three times a day they have a meal of corn, and the consistency gets thicker as the day advances. Thin mealie-meal porridge for breakfast, thicker porridge for lunch and even thicker porridge for dinner. And what goes with it? If they're lucky enough to buy cabbage, that's what goes with it. If it's the wet season, it's the natural-growing amaranth vegetable that they harvest. But most of the time it's maize, maize, maize and maize. This is true not just for Moses's family but many others. The low yields made Moses abandon the farm, but what's more important is that his wife and kids now have had to remain on the farm because that's the only profession that they have ever known.

Unfortunately, to this day, Moses's wife remains on the farm with his two children, who are now school dropouts. They continue to farm under rain-fed conditions using recycled seed and no fertiliser. The obvious reason for dropping out of school is lack of school fees, but when I visited the family farm recently, armed with a better understanding of hidden hunger, I asked to see the baby-clinic cards, and much to my horror I discovered that both children are stunted. Their birth weights were under the normal median curve, and their growth rates never pushed them beyond what was expected. But sadly no one ever explained this to Moses's wife because the children were round, they were fat and, according to any naked eye, they were thriving.

The effects of malnutrition in most of the villages are only diagnosed when a child is taken to hospital because of diarrhoea, dehydration or respiratory diseases, and only then do the nurses eventually say, "What exactly are you feeding your children on?".

Stunting and obesity

Unfortunately, Moses's children are not the only stunted children in Africa. The reality is horrific: nearly one in three children's deaths in sub-Saharan Africa occurs in the first month of life, and 64% occur within the first year. Up to 35% of the deaths among newborns and young children have malnutrition as the underlying cause. Sub-Saharan Africa is the only region where the number of stunted children is growing.

Immediate causes of stunting are poor maternal nutrition and poor health during pregnancy, and poor feeding practices for infants and young children after that. Research evidence shows that malnutrition is more severe at the level of poor rural households and smallholder farm families. The very people who are supposed to be producing food, not just for their families but for the whole country, are the ones suffering from malnutrition. Recent estimates of the prevalence of stunting and micronutrient deficiencies rank Africa as having among the highest rates in the world.

The largely irreversible damage of infant child undernutrition and poor growth and low cognitive functions impairs human productivity, and could lead to a reduction of at least 8% in a nation's economic development.

My recent experience in Tanzania and Ethiopia demonstrates that there are no special weaning foods for babies in the rural areas; they eat the same food as the adults. In a class of first- and second-grade children, up to half of the children I spoke to had come to school without having breakfast, the reason being the parents leave at the break of dawn to go to the farm fields and there's no one to make a fire and prepare food. Another one-third had had food but this was leftover food from the dinner. This would be just plain rice or plain maize corn, or teff in Ethiopia, mostly with no protein, just cereal and water – empty calories.

To make matters worse I've now learnt that the life-long sentence is not just stunting for these children; new evidence now suggests that the stunted children are likely to become obese as they grow up to be adults. As food, in most cases the wrong type of food, becomes available they compensate by eating more and becoming obese.

On obesity, the statistics are just as harrowing: worldwide obesity has more than doubled since 1980. The worldwide prevalence of obesity more than doubled between 1980 and 2014. Surely there is something that we are doing wrong, particularly those tasked with producing food. The cost of obesity and overweight-related non-communicable diseases was estimated to be $1.4 trillion in 2010. In 2014 an estimated 41 million children under the age of five years were overweight or obese. In Africa the number of children who are overweight or obese has doubled from 5 million in 1990 to 10.6 million in 2014. All this, we say, is a sign of development and affluence – as people become rounder and fat it shows they're well-fed! This we need to reverse.

Nearly half of the children under five who were overweight or obese in 2014 lived in Africa. And in 2014 more than 1.9 billion adults 18 years and older were overweight, and 600 million of these were obese. Thirty-nine per cent of adults aged 18 years and over were overweight in 2014 and 13% were obese. Most of the world's population lives in countries where overweight and obesity kills more people than just being underweight – there's no one country that is different. We are in it together. In 2015 approximately 795 million people did not have enough food, whilst 1.9 billion were consuming too much, manifesting in micronutrient deficiency, macronutrient deficiency, and overweight and obesity, the triple burden of malnutrition.

Need for nutrition-sensitive agriculture

There are several questions we need to answer. What is agriculture doing for nutrition? In our commitment to help the planet as enshrined in the 2015 Paris Agreement we may also ask the question: What are we doing for our planet?

I'll speak for myself and be the first to confess that after 25 years of development research work in agriculture it is only in the last three years, whilst working on the Agriculture to Nutrition Project, that I've come to understand what food security – nutrition security – truly means to the individual, and that we certainly need nutrition-sensitive agriculture. It is only now that I have broken out of the silo that I understand the perspective of the World Health Organization when it comes to food security. Unfortunately, as an agriculturalist, I'm embarrassed to say they've done better on nutrition than us who produce the food. According to the WHO, food security means that:

- all people, at all times, have both physical and economic access to enough food for an active, healthy life;
- the ways in which food is produced and distributed are respectful of the natural processes of the Earth and thus sustainable;
- both the consumption and production of food are governed by social values that are just and equitable, as well as moral and ethical.

They talk about ensuring the ability to acquire food; that food itself should be nutritionally adequate and personally and culturally acceptable; and that food must be obtained in a manner that upholds human dignity.

Surely we need to redefine what we mean by food security and nutrition security. The challenge that we face is really about knowledge, perspectives, and our siloed approach to development.

What is missing in agriculture

I spent my whole PhD years working on the productivity of small ruminants, the indigenous Matabele goats, focusing on how best I could feed the nanny goats during pregnancy and lactation to make sure that I reduced mortality, got high birth weights and made sure that we have more goats.

Little did I know that the more meat and the more milk were hardly ever consumed by the right people in the households. That 'last mile' is where most of us in agriculture rarely go: into the household to understand what happens to the food we produce. We have left this to social scientists and there are too few of them who understand the dynamics at household level.

Agriculture must have the 'culture' of giving dignity to the individuals that we aim to feed. And in addition to healthy people, there is a component that both the FAO and WHO definitions don't address, which is the issue of the environment.

We have not been able to address the components of a healthy diet holistically, and this then means there is something in agriculture that we are not doing right. That 'last mile' is the road that we need to push into, when we talk about research for development in agriculture, in environment, in health and in food systems.

A 'food-systems' approach prepares and creates those opportunities. How best then can agriculture deliver these positive nutrition outcomes? We've shied away from talking and engaging with behaviour scientists who make us do the right thing. We have actually let the health sector promote nutrition-specific interventions to deal with diseases that are created by agriculture. We've allowed the 'breast is best' message as pushed by the World Health Organization to be the one that's well known, rather than 'food is our medicine'.

We have not taken lessons in saying what it is that our agriculture can do. We have not thought about those mothers and the families that cannot purchase the vitamins that are promoted.

Surely, just as my grandmother's farm was her pharmacy, all farm families can produce nutritious food and healthy foods. It starts with healthy soils, fortified seeds, blended fertilisers, appropriate harvesting and storage technologies, nutrient-enhancing processing, fortification, cooking, preservation and – most important – the right policies that should be in place.

I'm excited to have had the opportunity to learn from the best, working through the Bill and Melinda Gates Foundation on nutrition projects at FANRPAN (Food, Agriculture and Natural Resources Policy Analysis Network). I have learnt how agriculture programs can be designed to be nutrition-sensitive and deliver positive health outcomes. Through working with the EAT-Lancet Commission under the guidance of Dr Gunhild Stordalen, Professor Johan Rockström and Professor Walter Willett, I have learnt that indeed we can have healthy diets and a healthy planet if we acknowledge what to do and are prepared to change behaviours and have a policy environment that penalises the bad and rewards the good.

The new narrative therefore should be 'Agriculture for healthy diets; agriculture for a healthy planet'. A farmer I met in Tanzania expessed it very well, in a phrase that translates to 'Eat for health and not for hunger' (*kula kwa afya – si kwa njaa*). Africa needs an agriculture transformation that embraces lessons from the Asian Green Revolution and crafts its own uniquely African Green Revolution. This one will be different: it's got to be smallholder-driven; it's got to be climate-smart; it's got to be nutrition-sensitive.

Steps towards an African Green Revolution

Let me share with you what I believe is needed.

First, we need to restore the dignity of the smallholder farmer: farming must be a profession of choice and not for the poor and uneducated. I'm happy to say a lot of effort is being put in now by strong farmer organisations that are going into electronic tagging to identify the *bona fide* farmers in the rural areas, looking at their asset base and making ways to retool through innovative finance and insurance packages.

Number two, we need robust market-led development-orientated institutions that can holistically drive the development agenda and promote the upscaling of what works. The era of pilots and small projects is gone. Let's take what we know works and put it to scale.

Number three, we need technologies that are packaged and promoted through advisory services.

Number four, we need a private sector that drives functional markets.

Five, and most important, we need functional accountable governments with good policy and regulatory services that will leave space for the private sector to thrive, but at the same time be true and accountable to serving the people. All of this is what Australia does very well.

There could be no better time to make things happen now worldwide. Under the Paris Agreement of 2015 we collectively committed to a better and climate-smart agriculture. This speaks to conservation agriculture, where you in Australia are the champions. It speaks to water harvesting and conservation techniques, where you are the champions. This speaks to precision farming and drought mitigation, where you have left an indelible mark.

Also, the Sustainable Development Goals speak to partnerships, and there can be no one institution, no one country, that can make it alone. We are in it together and no-one should be left behind.

Finally, it's the decade on nutrition; the UN has declared 2016–2025 as the Decade for Action on Nutrition. There is no excuse and no room for agriculture that does not deliver positive nutrition outcomes.

Making Africa 'work'

The time is *now* for Africa, according to my predecessor at AGRA (the Alliance for a Green Revolution in Africa) Dr Akinwumi Adesina, who is now the President of the African Development Bank.

- Africa has 65% of the uncultivated arable land left in the world to feed the 9 billion by 2050. So what does Africa have to do about its agriculture to make sure we have a food-secure world?
- Africa is the continent that by 2050 will have the same population as China and India have today.
- Africa is the continent that will be the most youthful continent in the world by 2050.

It makes sense therefore that I, together with everybody else, put our efforts into making sure Africa 'works'.

We need to industrialise our agricultural sector to unlock wealth. We need to achieve this through, not just the staple crops but all the diverse crops in our gene banks that we have not invested in enough, to make sure there's diversity in our diets.

We need to attract private business and agribusiness and get them to locate in rural areas. We need to create a market-pull for produce of farmers and reduce the high post-harvest losses in the supply chains. In so doing we're going to turn the rural areas from zones of economic misery to zones of economic prosperity. Africa already has some formidable institutions.

- The Pan African Farmers Organisation under the leadership of Dr Theo de Jager, a South African farmer, has been doing sterling work in organising farmers across the continent.

- The Forum for Agricultural Research in Africa (FARA) is driving strategic science partnerships designed to respond to emerging opportunities.
- Under the Comprehensive Africa Agriculture Development Programme (CAADP), led by the African Union, there are new declarations and commitments to make agriculture the benchmark for African economies.
- On the policy front there is FANRPAN, the multi-stakeholder platform that is bringing governments and civil society to design evidence-based policies, and 'Grow-Africa' which has brought 200 private sector companies into 12 African countries to make formal commitments on respective country investments in agriculture.
- And AGRA, designed to be an alliance, has attracted the largest collection of agricultural technical experts on the continent with areas of specialisation that include the full value-chain, from developing seed varieties that are adapted, fertiliser blends and agronomic best practices, to connecting farmers to markets, all in an effort to make sure that African agriculture is transformed.

It can be done. It's been done under the leadership of Dr Agnes Kalibata who left an indelible mark in Rwanda as the Minister of Agriculture. AGRA is well positioned by having government support, technology and private sector involvement to make sure that the African Green Revolution does not remain a dream, but is a reality.

All I can say is that Africa is more than ready for win–win partnerships. The new narrative for nutrition-sensitive and climate-smart agriculture is forging new partnerships of learning together and sharing experiences for healthy people and a healthy planet.

We owe it to ourselves, because the stunted children of today are the leaders of tomorrow, with whom you will have to sit around the table to negotiate deals. We cannot afford that. They may be the immigrants of today, but tomorrow they may be the citizens that can bring hope to their own countries as dignified economic migrants.

As we enjoy our dinner tonight, think of Moses and his corn porridge and cabbage, just to fill his tummy, and also his two children, now 17 and 15, physically small for their age just like many other children in the village. But sadly you and I know that they are stunted for life, their cognitive capacity is compromised. Worse still, their mother Mrs Moses is obese and has recently been diagnosed with diabetes. That, ladies and gentlemen, is a lifelong sentence that has been caused by bad agriculture.

We need a new narrative to end hunger, one that speaks to quantity *and* quality; a narrative that breaks the old way of thinking; a narrative that ensures healthy people and a healthy planet. The agriculture I learnt at college spoke to quantity, on the assumption that once there's more, then people will have income to buy the right food. The agriculture that my grandmother taught me was about quality.

We need to end hidden hunger. We need to increase yields – yes, I agree. We need to promote diverse diets. We need to empower women and make sure

women are getting into pregnancy healthy, they're staying healthy during pregnancy, and they're staying even healthier as they breastfeed up to the second birthday of their children. This is the first thousand days that is promoted by the health sector – and we pushed back on the agriculture side, not knowing it's talking about the food we produce.

We need a new definition of food and nutrition security that relates to individuals. It is the nutritional status of the individual household member that should be the ultimate focus, and the risk of that inadequate attention is something we cannot afford.

Let's make food our medicine, and reduce the ballooning health bill fuelled by bad agriculture.

I believe we can end hunger, particularly in my continent which is lagging behind, if we do what we know is right, if we forge responsible partnerships, both in government and in the private sector. This is the sweet spot that will open the way for an agriculture that is impactful and can lead to a new narrative for a uniquely African Green Revolution, and end not just hunger but eradicate poverty. We owe it to ourselves.

I am sure my grandmother – if our ancestors do smile wherever they go – Gogo Mahembe would be smiling if we all commit to nutrition-sensitive agriculture. But better still, Sir John Crawford would also be smiling. I thank you.

Lindiwe Majele Sibanda is Vice President for Country Support, Policy, and Delivery of the Alliance for a Green Revolution in Africa (AGRA). Globally, Lindiwe is a recognised leader and has served as trustee and adviser to numerous international food security-related initiatives. Prior to joining AGRA, Lindiwe was the CEO and Head of Mission of the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN), responsible for coordinating policy research and advocacy programs across 17 countries aimed at making Africa a food and nutrition-secure region. She is a serving member of the SDG Target by 2030 Champions 12.3; a Commissioner for the EAT-Lancet Commission on Sustainable Healthy Food Systems; the United Nations (UN) Committee for Policy Development (CDP); and the African Union Commission (AUC) Leadership Council. She has served as a university professor in agriculture, animal sciences and veterinary sciences, and she is a regular guest lecturer at several universities. She is a recipient of numerous awards for her contribution towards agriculture and food security in Africa, including: the Science Diplomacy Award by the Government of South Africa (2015); FARA Award for Exemplary Leadership (2014); and Yara 2013 Prize Laureate (2013). She is a trained animal scientist, an authoritative leader in agriculture, climate change and nutrition. She holds a BSc (University of Alexandria, Egypt), and MSc and PhD from the University of Reading, UK. Lindiwe was recently appointed a member of the ACIAR Policy Advisory Council.

Ministerial Opening

The Hon. Barnaby Joyce MP

Deputy Prime Minister

Sir John Crawford is one of the giants of Australia, and it's a pleasure to open this Crawford Fund conference. What I have always respected about Sir John Crawford is not only his obvious attachment to economics, with the Crawford School of Economics, but also his attachment to agriculture, setting up the Bureau of Agricultural Economics.

Why would it be so important to link these two? It is because you never get a purer form of economics than in relation to the capacity and the requirements of humankind to be sustained. We are in a noble profession in agriculture because our job is not to rip people off; our job is to feed and clothe people, and it's a mighty equation. And I've said this whilst in Europe and also in Asia, that if we get this equation wrong then the most dire thing happens: people starve to death. Therefore we have to stay on our toes.

What does that equation look like, ladies and gentlemen? Well, we're going to have 10 billion people residing with us by 2050 and they are sustained by protein, they are sustained by carbohydrates, they are sustained by fats, they are sustained by some sugars, they are sustained by garments. And, ultimately, that sustenance comes off the land, and our capacity to provide that sustenance is the art form that we dedicate ourselves to.

If you want to look at it another way, in the next 50 years – the next 50 years – we have to produce as much food as humankind has consumed to this point in time. We've had the Green Revolution with Norman Borlaug who has helped in the past. We saw the incredible turnaround, I think it was between 1946 and 1963, a six-fold increase in the wheat yields of Mexico. But unfortunately we've kept procreating and the population's caught up, and now we have to take that next step. And that next step is going to stand on the back of research and innovation in ways we've never seen before.

When we look at it, mankind (as a generic term) has had its revolutions in the past. If you look at the wheat gene as a hexaploid gene, it's more difficult to map than the human genome because we've been messing around with it for about 10,000 years, waiting for the providence of some mutation that we can build on in such a way as to increase the yields. You can see this is almost self-evident, not only in the genetics of wheat but also in the agronomic expertise that sits behind that.

In Rothamsted, in England, there is the longest running agricultural experiment in the world. It's been going for about 160 years, and in those Alternate Wheat plots (if you ever get a chance you should have a look at them because that is, in live form, the equation that's before us), one plot of a hectare produces about

Paper prepared from a transcript of the presentation.

a tonne of wheat. With the same variety in a plot right beside it – on the same soils (and they're not very good, to be quite frank) but with all the herbicides and fertilisers and the issues that we have used our endeavours to build over time – you're getting 8–9 tonnes to the hectare.

The difference between those two is called starvation, and the difference between those two is called excess, and of course excess and economics bring advancement to economies because you have tradeable outcomes. So this is the great attachment between economics and agriculture.

We continue to put our minds to research and development. One of the scarcest resources in Australia is water. We've applied about $13 billion to the Murray-Darling Basin. Why? So we can get better efficiency from each unit of water. And if you look within that water-use, one of the greatest increases in efficiency has been in the cotton industry.

Now sometimes the cotton industry is labelled a pariah, and I get annoyed by that because it's just like creating witches and throwing rocks at them. When I started some years ago in banking, we were allowed to say that the yield from an acre of cotton (we used imperial measures then) was 2.7 bales. If we said someone got a higher yield than that we had to tell the credit bureau why we believed this farmer was achieving an exceptional return. Nowadays, if you are getting 2.7 bales to the acre you will go broke very quickly. Now we are talking about 5–6 bales to the acre, which means, of course, you are using half as much water as you used to use. This is another form of efficiency. How? Well among other things it is because of genetic modification. This is one of the big debates we are going to have to have. If you don't believe in genetic modification, then if you've got a cotton shirt on, or cotton underpants or a cotton singlet, take them off, because it's all genetically modified. And while you're at it, remember that cotton seed is fed to cattle, so you had better stop eating beef as well.

We don't have the 10,000 years for the development of the hexaploid gene in wheat to get ourselves to 2050; we have merely a couple of decades. And we don't have the Green Revolution. Even that took a number of decades – time that we don't have in front of us. We are seeing right now that there is a downturn in nutritional intake, and more people under nutritional stress; that is happening right now! If we get this equation wrong, they will die. You won't see them – they won't be dying in Australia – but if this stack called the food bank, the quantity of food in the world, is unable to meet requirements then somebody, somewhere, is going to die, probably starting in Asia or in Africa, and maybe eventually in the Pacific Islands, but it will happen.

So we have an incredible responsibillity, and this is why Sir John Crawford was so intent on issues such as dealing with tariffs, because you've got to have the free movement of food, the free movement of these products. You can't have a religious perspective about it; you have to have a practical perspective about how you deal with this issue.

I get a great sense of joy that agriculture is now the responsibility of the second-highest office in the land. Agriculture and water resources – and now minerals

in northern Australia as well. But we have to have debate about how we deal with issues such as intermodal transport, our capacity to move bulk products quickly and efficiently – we've got to have that discussion! We have to discuss developments such as inland rail to try and take the next step forward.

We have to have discussion about where to develop our water resources, new dams, so we can open up new areas. We have to continue in our research and development of paddy-free rice, because we know that growing rice in paddies in many instances offers a very cheap form of weed control and deals with the issue of diurnal temperature range (because the rice plant is not resilient to large daily temperature fluctuations).

If we can manage those factors we will have the capacity to start feeding more people and to show people our providence in doing the research and having the economic expertise to make this equation work.

Sir John Crawford, born in Hurstville in Sydney as one of 12 kids, working for the Commonwealth Bank, working day and night, had the aptitude to look out into country areas and say, "Here it is, this is the equation; this is what we've got to look at; this is what we've got to work out; how we fix this problem". And our nation has a vital role to play in this, an honourable role to play – an incredibly honourable role.

That you can say, "I've dedicated myself to clothing and feeding people; the results of my endeavours are that people are eating, people aren't going hungry" – that is an incredibly powerful thing and that's one of the things that keeps me attracted to agriculture even when people say to me, "Do you want to move to another portfolio? Go somewhere else?". This is it! If we get this right and if we can build on the work done by people such as Sir John Crawford, then we're doing a great job!

So I wish you all the best for today's conference. I look forward to seeing the outcomes, how we can deal with these issues. I trust you won't start saying, "Oh well, we're going to talk about this equation but we can't talk about rice. We're going to talk about this equation but we can't talk about cotton. We're going to talk about this equation but we refuse to talk about genetic modification. We're going to talk about this equation but we're going to start imposing on others ideas that are not really our business but theirs – such as 'you've got to stop having babies' ". No, I trust you will talk about the equation seeing the reality of what is before you, and working out how you're going to fix that.

We have to apply our minds and our endeavours to how we keep the free movement of trade, how we get the intermodal transport going, how we put the dams in place, how we work with the genetics so that we can get the best return per unit of land.

We have to stay mindful of the person in Asia or in Africa or the Pacific Islands, and be able to say, "Well, if I get this right, they eat".

If we can do that, your endeavours and the labours of your brain and the labours of your hands have a noble outcome. All the best and God bless.

Deputy Prime Minister, National Party Leader and Minister for Agriculture and Water Resources, Barnaby Joyce, has been a member of the Federal Parliament since 1 July 2005 when he assumed the Queensland Senate seat he won at the 2004 federal election for the Nationals. Minister Joyce is currently the Nationals Parliamentary Federal leader. Previously, Minister Joyce was the Deputy Federal leader to Deputy Prime Minister Warren Truss after leading the Nationals in the Senate for just under five years. On 8 August 2013, Minister Joyce resigned from the Senate to contest the House of Representatives seat of New England at the September 2013 federal election. The seat had been held by independent MP Tony Windsor. In winning the northern NSW regional seat, Minister Joyce became the first person in Australian politics to have represented one state in the Senate and another state in the House of Representatives. In Opposition, Minister Joyce held a number of portfolio responsibilities including being the Coalition spokesman for Finance and Debt Reduction (2009–10), for Regional Development, Infrastructure and Water (2010), and for Regional Development, Local Government and Water (2010–13). Minister Joyce was the fifth child in a farming family of six children. He was born in Tamworth and grew up at Danglemah, where his family owned a sheep and cattle property. He was educated at Woolbrook Public School and St Ignatius College, Riverview. He studied at the University of New England where he gained a Bachelor's degree in Financial Accounting. Minister Joyce practised as an accountant, as a rural banker, and ran his own accountancy firm in St George, Queensland, for 10 years. Minister Joyce was appointed as Agriculture Minister on 18 September 2013. As well as his ministerial responsibilities, Minister Joyce was also appointed as chair of the Prime Minister's Water Infrastructure Ministerial Working Group. On 21 September 2015, Minister Joyce also assumed portfolio responsibility for water policy and was sworn in as Minister for Agriculture and Water Resources. On 11 February 2016, Minister Joyce became the Leader of the Nationals and on 18 February 2016, was sworn in as Deputy Prime Minister.

Keynote: How can 'big data' transform smallholder farmers' lives and livelihoods?

André Laperrière

Global Open Data for Agriculture and Nutrition (GODAN)

Abstract

For many years 'big data' has been considered by many as the privilege of the few. Because of its volume, it could only be handled by large corporations, essentially based in the west; because of its complexity, it required high level specialists to manage it, and because of the cost of putting it together, it rested out of reach of the common person's purse. This has changed.

During this lifetime, the world has gone through three consecutive and very fundamental revolutions. The *first* was the Internet connecting the world together. The *second* was the emergence of intelligent devices, starting with mobile phones, bringing knowledge to your fingertips. The *third* revolution is here: *open data*.

Knowledge can now flow across the world with accuracy, at a speed and volume never reached before. The world of agriculture is one of the key beneficiaries of this latest revolution, seeing for the first time the innovative benefits of a true 'cooperative development process' taking place. Governments are opening their data; research is working hand in hand with the private sector; and civil society – consumers and farmers alike – is voicing its needs and triggering innovation tailored to its capacity, situation and choices. As a result, even in the most remote areas today you can see applications using the latest technology – and 'big data' – in the hands of farmers and in a form and shape that makes sense for them. Applications are affordable and manageable, allowing their users to gradually overcome subsistence farming to reach a higher quality of life. Globally this means that continents where agriculture is still the key development engine see their economy improving, hunger decreasing and innovation flourishing. This is what will lead the world to overcome the emerging food security challenges ahead of us, and contribute greatly to allow developing countries to reach their full potential. This presentation describes this process and gives concrete examples of where and how 'big data' is now used by small farmers; and more generally, how open data is changing the face of global agriculture.

Yesterday I was having a talk with someone whose background happened to be in History, and it made me think of a connection between History and the 'big data' we are talking about today. Those who are familiar with Greek mythology know that a long time ago, the mountain in Greece called Mount Olympus (then called Olympus Mountain) was believed to be where the gods lived. The mountain is very high, so of course usually the top is in the clouds. And in the

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

Mount Olympus: often in cloud and historically out-of-bounds to everyday people.

old days all the gods were there doing their god-business while regular people were down on the ground trying to do other things. Humans were not allowed to go up to the top of Olympus Mountain, of course, because that was a sacred area. The only interaction they had with the gods was that every now and then if one of the gods was not too happy a lightning bolt would come down and toast someone. That's the way it was, so people lived in fear.

But times have changed. Now there's no more fear. Now humans are allowed to go to the cloud. Better, they are allowed to use it – and what do they find? They find that there is a lot of knowledge in the cloud. Our challenge is to get there and make use of it.

I would like now to share with you this [transcript of a] very short video clip:

> *Over seven billion humans inhabit planet Earth. Experts tell us we collectively produce more than enough food to feed everyone. But why do eight hundred million people still go to sleep hungry every night? And why do over three million children die every year due to malnutrition? The causes are many. The problem is global. Solving the problem of global food nutrition security is complex. Perhaps the solution is right before our eyes. If only we could see the entire picture, the solution is breathtakingly simple. The answer to zero hunger lies within existing agriculture and nutrition data. Right now this information is inaccessible to many. This is why we believe in making this data open and available for unrestricted use worldwide, to combat hunger, promote innovation, create economic opportunities, empower farmers and improve the health of everyone. We have the opportunity right now to end world hunger. All you have to do is lend your voice to tell public, private and non-profit organisations to commit to making agriculture and nutrition data open and freely available. Together we can be the generation that takes the most important step to end world hunger by setting agriculture and nutrition data free*.

GODAN: Global open data for agriculture and nutrition

In Sanskrit the word 'godan' means 'gift', a gift of god, or something that everybody should aspire to do in their life. GODAN was created just a few years ago, after discussions at the 2013 G8 International Conference on Open Data for

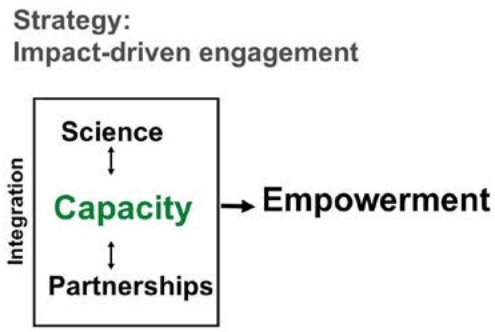
Agriculture. Somebody there said, "Hey, by 2050 there's going to be 50% more people on this planet. So what are we going to do?".

We have to find ways to produce more nutritious food to feed all these people. The Food and Agricultural Organization of the United Nations (FAO) says there will need to be around 60–70% more food than we are making available today. It is quite a challenge. To put it into perspective, the additional food we need to produce this century is equivalent to all the food that humanity has produced in the last 8000 years.

The world is trying to address this need from many very different angles, and there are several complicating factors. One such factor is demographics: it is difficult enough to continue to produce food the way it is produced now, and with 50% more people coming in the next 30 years we shall need to drastically increase production. A second complication is climate change, because it is already difficult just to maintain current production levels: land degradation is prevalent; sea levels are rising; the Earth is warming up. In many places where agriculture used to thrive it is struggling now, for lack of water or simply because the temperatures are too high. What can we do?

We can use technology. Technology is making incredible things possible today. As you may have realised, in our lifetime we have just been through three major world revolutions. They have been quiet revolutions – no noise – but they have transformed humanity. The first revolution was the Internet. Internet has connected the world, enabling people across the world to speak to each other or be able to do so in a fraction of a second. The second revolution was intelligent phones, because it brought the Internet to your hand. Wherever you are – in the car, at home – you can access a wealth of information that may physically be on the other side of the planet. And the third revolution, which is even quieter but much more important, is data, and especially *open* data. Open data is knowledge – if we can shape it and make it available in a form that makes sense to you the user and helps you solve a problem that you have.

GODAN's strategy relies heavily on partnership, and on science and therefore on knowledge and data. We need partnerships because even though people have different specialities – mine may be genomes and yours may be satellites for example – but yet, if we talk long enough we may be able to combine some of the expertise we have to produce *impact*. Impact works by giving knowledge to people, empowering them, as illustrated in the diagram below.



Data leads to knowledge, which in turn allows for empowerment through better choices. With data, a government can make more enlightened decisions, better policies, because it has a better picture of the situations existing in its country. Citizens can make better choices in their requests to government because they have better knowledge of what is available and what can help them. The private sector can make better choices in designing services, applications and products that meet the needs of the population because they know more about them.

GODAN has a presence all over the world (Figure 1), and we are trying to bring together ideas from Latin America, from Asia, from Europe, and see what happens.When we combine them we find innovation: the impossible suddenly becoming possible. That is the kind of outcome we are aiming for.

Examples

Some examples may show how GODAN works at all levels. We are helping governments work out a policy environment that will help data arise and thrive, starting with their own data which you pay for with your taxes, to make it available to you in a way that makes sense. We are also encouraging other sectors to do the same. Some have done it officially. The Dutch recently established a private-sector public-sector data partnership, to see how they can use a common platform to make this wealth of joint information available. In June in Nairobi, GODAN was invited to co-host a very important meeting, at the end of which the Nairobi Declaration involved 15 different African Ministers, agreeing to a roadmap in terms of structuring and implementing open data in agriculture in their respective countries (Figure 2). This is a first for Africa, and maybe for the world, so we are very very happy about that outcome.

Those examples are at the policy level.

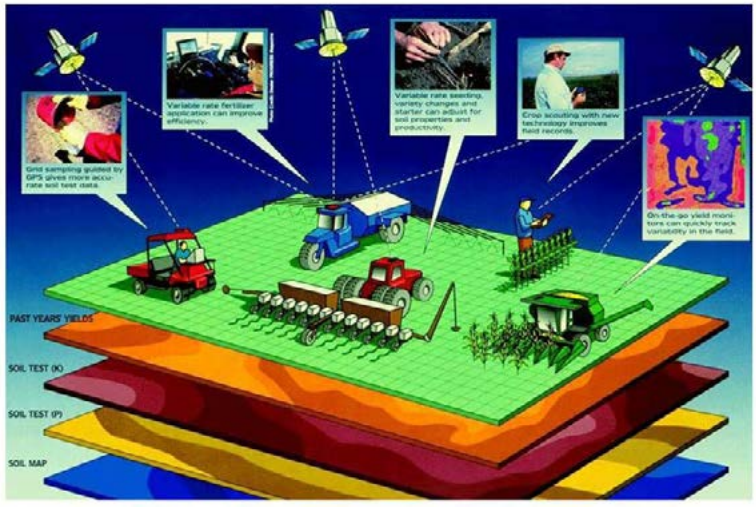
Below policy level, one of the objections we face is that some people ask, "Where is the data? Is there enough data? Where is it?". The answer is that there is a 'massive amount' of data already available out there, and growing fast. To give you an idea, by 2025 the world is going produce somewhere around 180 zettabytes of data (where 1 ZB = 10^{21} bytes). Looking at this another way,

Figure 1. GODAN has over 550 partners worldwide: 10 or more partners in areas with yellow discs; 2–9 partners in areas with green discs.

Figure 2. Summary of Day II, Ministerial Conference on Agriculture & Nutrition Data, June 2017: 1. Strengthening agricultural and statistical data systems in Kenya. 2. South–south dialogue: How data is enabling innovations in agricultural value-chains. 3. Mutual accountability for consolidating gains and delivering actions to achieve.

every day the world generates enough data that if it could all be loaded onto CD ROMs, that daily pile of CDs would be almost the height of the Eiffel Tower.

There is no shortage of data, but what makes its use difficult is that it is not very well structured. We are pushing for data integration, so that data coming from satellites can be combined with data from drones, from FAO, from traditional sources, and so on. We need to combine the data retroactively also, because when you know better what is happening now because you have corrected or improved your data, looking back you are in a much better position to predict what's likely to happen, and therefore to be able to prepare before catastrophes happen or before opportunities occur that you would otherwise miss. That's what the diagram below attempts to represent.



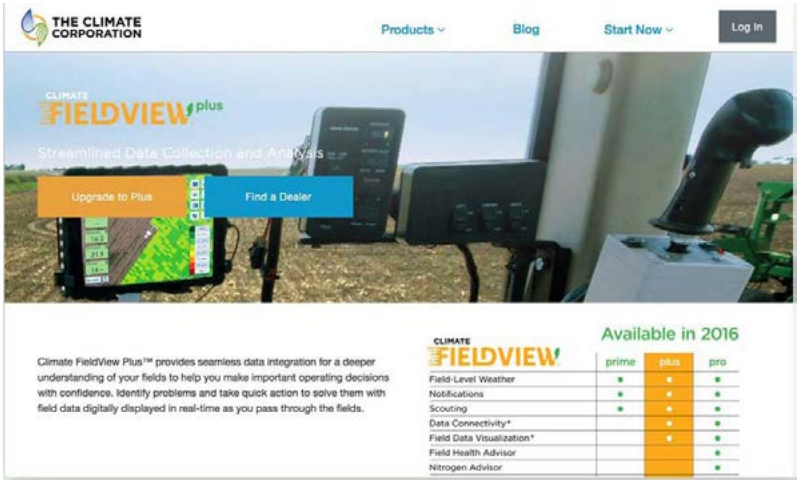


Figure 3. High-tech data loops.
'Climate FieldView Plus™ – seamless data integration for deeper understanding of your fields to help you make important operating decisions ... field data digitally displayed in real time'.

At a different level again, Figure 3 shows the view my neighbour has on his tractor. This software is a product of one of our partners, Climate Corporation. They bring various sources of data to the farmers, and use very sophisticated sensors that help guide with high precision, whether the job is ploughing or fertilising or harvesting. And the little electronic tablet to the left of the view is not just plotting the course and applying fertiliser only where it's needed, thereby saving money, but it also allows the farmer to make simulations. He or she can explore how the crop might respond to a different type of fertiliser, for instance. This capability would have been a miracle five years ago but is now common practice. My friend can hardly use his intelligent phone but he can drive this tractor software ... in fact, he says he doesn't drive it; it drives by itself.

Figure 4 at the top of the next page comes from South Africa, from satellite data. That is the new way to the future. The Sentinel series and others with the latest generation of sensors can give you not just pictures of where the clouds are but also tell you the condition of your soil, whether it needs water, the quality of the biomass and therefore whether you need to fertilise or not, or which part of your land is in trouble and which part is not. This was a small project in South Africa and the same technology is being used in Ethiopia and other places. These services are available to the farmers for a nominal cost through co-operatives or small enterprises because the cost is being shared by a lot of people. The aim in this specific project was to reduce water consumption in this area that you see, by 10%. The end result was that they reduced it by 30% and they more than doubled the land that they were able to irrigate, because of precision irrigation consumption.

Amazing things can be done using technology, and using models that put data in the hands of the farmer.

Figure 4. CropScan software showing accumulated biomass on a farm in South Africa.

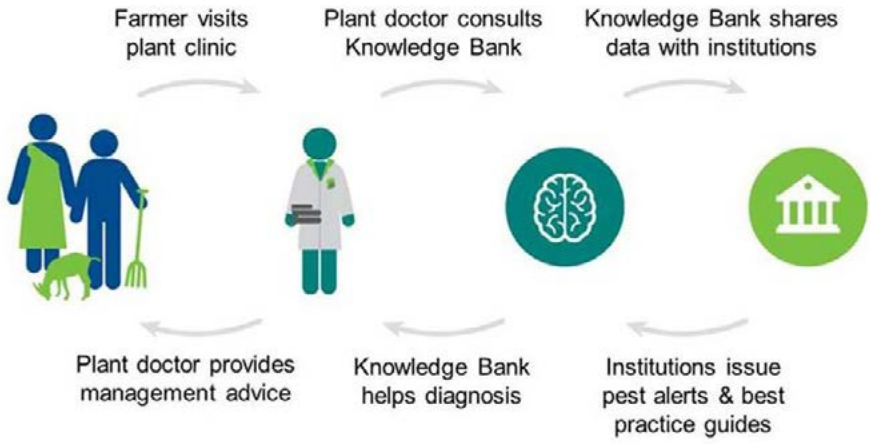


Figure 5. 'Big data': a two-way flow of information through CABI's 'Plantwise' program.

The diagram in Figure 5 depicts the 'Plantwise' system run by CABI, one of the many programs in the GODAN network. The important aspect of this data-sharing is that it is a 'two-way street'. It is not just plant doctors telling farmers what they have to do. Instead this is a win–win situation. The concept is like this: people trained in basic agriculture are available as plant doctors, and if you find your maize or your rice is struggling for some reason and you don't know why, you can call the plant doctor. He or she comes and looks at your crop and tells you what the problem is and offers a remedy. Then the plant doctor goes back and enters this information into a database which, day by day, becomes bigger and more comprehensive. The next time the doctor is called out he or she has more information and is in a better position to give advice. The knowledge base grows and becomes more and more useful to help the farmer. It also helps the

government help the farmers because it can intervene when it sees multiple cases of a certain infestation, say, in one region.

Another aspect of the Plantwise model, illustrated above, has been devised by another GODAN partner, Bayer. They have made it possible for the farmer to take a photo of his affected crop and send that photo to a central database using Artificial Intelligence. In a very short time, even seconds, a response tells the farmer the cause of the problem and the remedy. If for some reason the problem is new to the database, the response message will include contact details for a person who can discuss causes and solutions. As you can see, technology and data are developing fast.

Some people do not have a mobile phone, though that is an uncommon situation. And there can also be language differences. That is why our aim is to be able to provide knowledge and data *in ways that people can understand*. A good example comes from Ethiopia where, acknowledging language differences, they created a hotline for agriculture (Figure 6). If I am a farmer somewhere in northern Ethiopia and my maize is struggling and I don't know why, I can call the hotline and speak to a human being who has access to this database and can give me the information I need. In the first three months of this hotline in Ethiopia, there were half a million calls. Overall, around a million farmers are using this system – another form of sharing open data, sharing knowledge with the farmers.

Summary

In conclusion, we are working towards big data for the 'little guy'. Data should be available to all of us.

Findable: First, we have to be able to find it. So when people publish data, especially research data, they should put it where people can find it.

Figure 6. The range of languages in Ethiopia led to a hotline being set up for agricultural advice: a form of 'big data' that users can understand.

Accessible: Second, the data needs to be accessible without needing three levels of passwords, or membership of a club or something like that.

Makes sense: Third, the data has to make sense. Satellite data is a good example of data that is too complex for me if I am a small farmer. I just need to know why my maize is dying, so the data I access has to be in a format that I understand.

Solving a problem: Fourth, big data needs to solve a problem. As we identify problems and do the research to solve them we must be generating data that is useful, and we must make it available to humans, not just to the gods on the Olympus Mountain.

André Laperrière joined the Global Open Data for Agriculture and Nutrition (GODAN) initiative as its first Executive Director, in September 2015. Before joining GODAN, Mr Laperrière was Deputy Chief Executive Officer at the Global Environment Facility (GEF) in Washington DC. During his career, Mr Laperrière has led or managed numerous projects on behalf of large private corporations and subsequently within the United Nations and the World Bank. In this context, he played a senior role in the design and implementation of major reforms within a number of agencies, such as the International Criminal Court (ICC), the World Health Organization (WHO) and UNICEF. He has extensive work experience in the Americas, Caribbean, Africa, Europe and the Middle East, in particular in developing countries and in conflict and post-conflict environments.

SESSION 2: USES AND CHALLENGES OF 'BIG DATA' FOR AGRICULTURAL DEVELOPMENT

Overview: **Local applications for global data and AI**

Steve Mathews

Gro Intelligence

Abstract

'Big data' has great unrealised potential in most parts of the agricultural value-chain. We can divide that data up into several categories, each with its own good and bad points. Starting in 1972, the US Landsat program collected the original 'big data', but capability to perform meaningful analysis of the photos remained very expensive until recently. Other flows have begun in the past few decades, from private satellites, point-of-sale systems, land-based sensors, and aerial drones. Unlike Landsat, the various newer sources have different ownership statuses. Globally, most smallholders don't generate the revenue to pay for any of the various proprietary data sources or analysis. But we see significant value in the application of machine learning/'big data' techniques to publicly available satellite and other sources. Advances in information technology allow us to disseminate good-quality yield, drought, and other analyses at a much lower cost than previously. As a result, relatively small external contributions can bring the established benefits of modern modelling expertise to a hugely broader and more diverse audience.

In my prior career I was researching and trading commodity futures and options, for agriculture as well as metals and energy. Apart from that background, my experience in 'big data' and modern analysis techniques in agriculture comes almost entirely from my company, Gro Intelligence. I tell you that because inevitably in this talk I am giving you the company's viewpoint on these sorts of analyses. I strongly believe, along with others, that the things that Gro Intelligence is doing and has done are important to enable farmers and smallholders in sub-Saharan Africa to make progress, because for these groups there are many issues that do not seem to be being solved by the data currently available to them.

Agriculture is still at the very early stage of using modern 'big data'. Energy, banking and transportation are way ahead and those fields have many lessons to teach us. Those industries are still working 'full speed ahead' and moving forward at the same speed we are, I would say.

The McKinsey Global Institute built a digitisation index for the US (Figure 1): a matrix of green, red and yellow squares that indicate the level of preparation

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

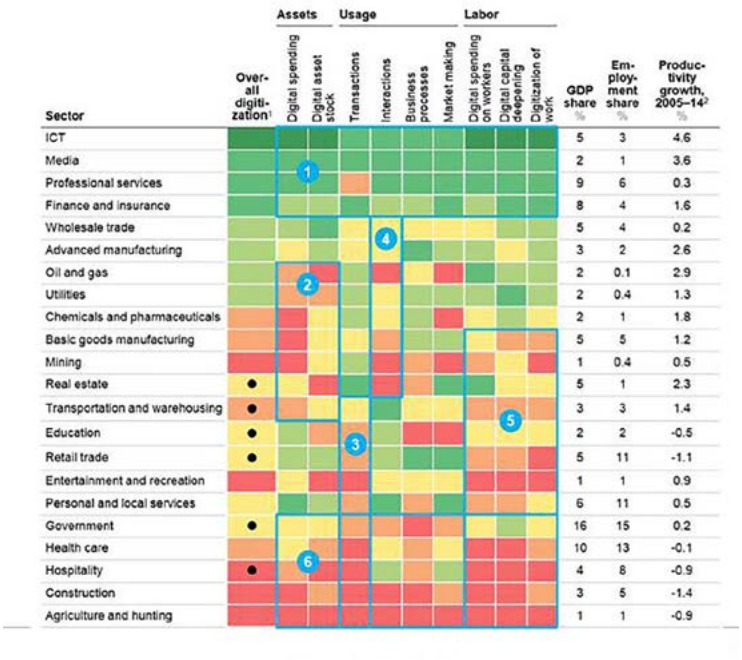


Figure 1. McKinsey Global Institute Digitization Index up to 2014: ICT and media at top, all green; Agriculture & Hunting at bottom, all red.

of each industry in that particular area of 'big data' or digitisation in general. At the bottom is Agriculture (& Hunting), shown in red for all the rated categories (grouped under Assets, Usage and Labour). Agriculture rates lower than mining, government and hospitality, all of which are also fairly far 'behind' (in comparison with other sectors in the US) in their uptake of digital technology.

Agriculture is only just starting to look at large-scale low-cost parallel processing, distributed storage of data, access to better data from private satellites, point-of-sale systems, land-based sensors, aerial drones and individual farmer smartphones. These can be transformational in the long-term, encouraging private sector activity and attracting the types of agricultural investments that can help make the sector more resilient.

Making agricultural data valuable to business

Gro's insight was that, although poor farmers in Africa know a lot about their farms and are not always easy to convince that computer tools can help them, there are people affiliated with them who do understand, or may understand, the role of data, and may have the capability to pay for that. Gro Intelligence is a 'for profit' company but we are working on this in parallel with non-profit and NGO-type activities, and other companies in our area. We think that more sophisticated analytics that respond to the marketplace and respond to customer demand definitely have a place. That is where solutions like ours can help agriculture to make progress.

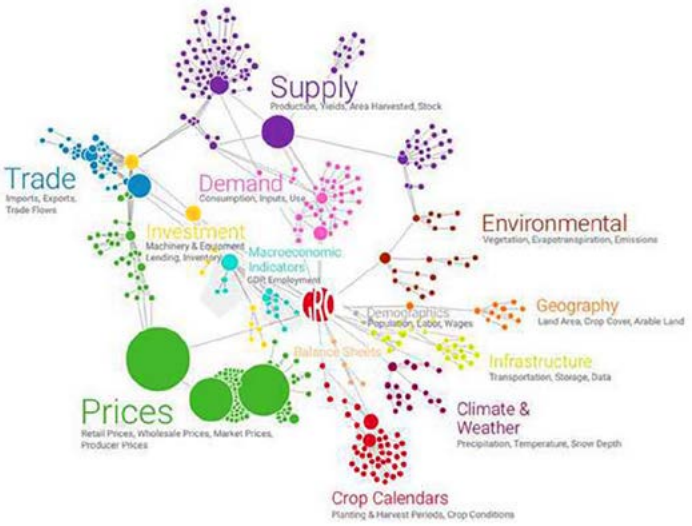


Figure 2. Gro Intelligence's proprietary ontology.

At a high level, Gro Intelligence is a fairly simple and straightforward company: we take in data from disparate sources, manipulate it and disseminate it to disparate clients. In my opinion, we add a lot of value in that middle phase of manipulation.

We have used a cadre of experts in agronomy, geospatial data, cartography, statistics, computer science and finance to create an ontology. (An ontology is a taxonomy without the requirement for hierarchy; in biology, for example, the taxonomy of every known species of life on the planet places them in a strict hierarchy.) The ontology Gro Intelligence has built is designed to help agribusiness understand the meaning in the agricultural data we collect.

Gro's proprietary ontology avoids the concept of hierarchy so as to create greater value for commerce. Building an ontology of that nature takes a lot of sophisticated work and the outcome is hard to picture (illustrated in Figure 2 in two dimensions).

We are in contact with agricultural trade and statistical agencies all over the world and the data we routinely receive is in a range of formats often derived from collection or processing in local units or standards, and in some cases using archaic methods. Bushels per acre versus kilograms per hectare is just the start. Different crop years, even different calendar years, changing borders and nations – it's a mess! We have done and continue to do a lot of work to make the data accessible and useful. Furthermore, we constantly assimilate more sources and data into the framework. As well, Gro has integrated geospatial information from satellites and other sources.

Landsat images of Earth were the world's first data that could be really qualified as 'big', and they began to be collected in the early 1970s before there was widespread ability and capable equipment to handle them. Now, the geospatial

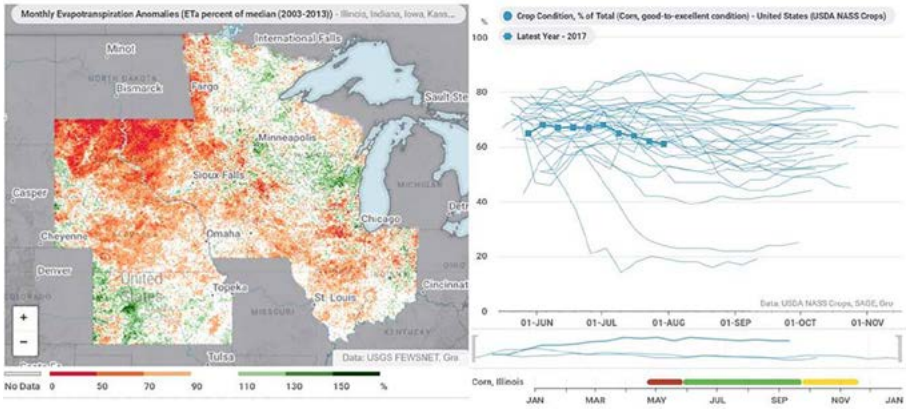


Figure 3. Satellite pictures (left) are converted to actionable indices (right).

team at Gro Intelligence, comprising five fulltime scientists in New York and Colorado, extract more useable insights from satellite pictures each day. The data rolls in daily in gigabytes and is stored in our multiple petabyte database.

Examples

Data is only as useful as what you can do with it. Visualisations, charts, maps, calendars – things of that nature – allow users to access the information in unanticipated ways that mean something to them.

Some of our users now need only minutes to access data that took them days, weeks or even months to partially obtain through manual data research projects. Another set of our users is accessing data at large-scale for the first time, because previously it was only available to institutions that could afford to employ entire data teams. With new technology we can pool and analyse trillions of agricultural data points from a variety of sources, such as government reports, satellite imagery and weather forecasts, to give them universal meaning and to give users insight.

Geographic information systems (GIS) link satellite imagery to ground-collected information. Geospatial knowhow means we can distil a complicated and colourful map into a single index which summarises the whole picture (e.g. Figure 3). You can see a crop calendar there on the bottom of the line chart. The GIS expertise in our team allows us to take those geospatial data points that you see on the map on the left and sum them within almost arbitrary geographic regions – down to state, county, district level, whatever you require.

Machine learning techniques applied to those various data series, which include ground-collected data, satellite data or other types, can then generate predictive models. Machine learning can seem like a 'black box', and I don't want to 'get into the weeds' on the subject. But great advances made recently mean that we can now use machine learning very inexpensively, at a low level, to generate models which are better at prediction than previously.

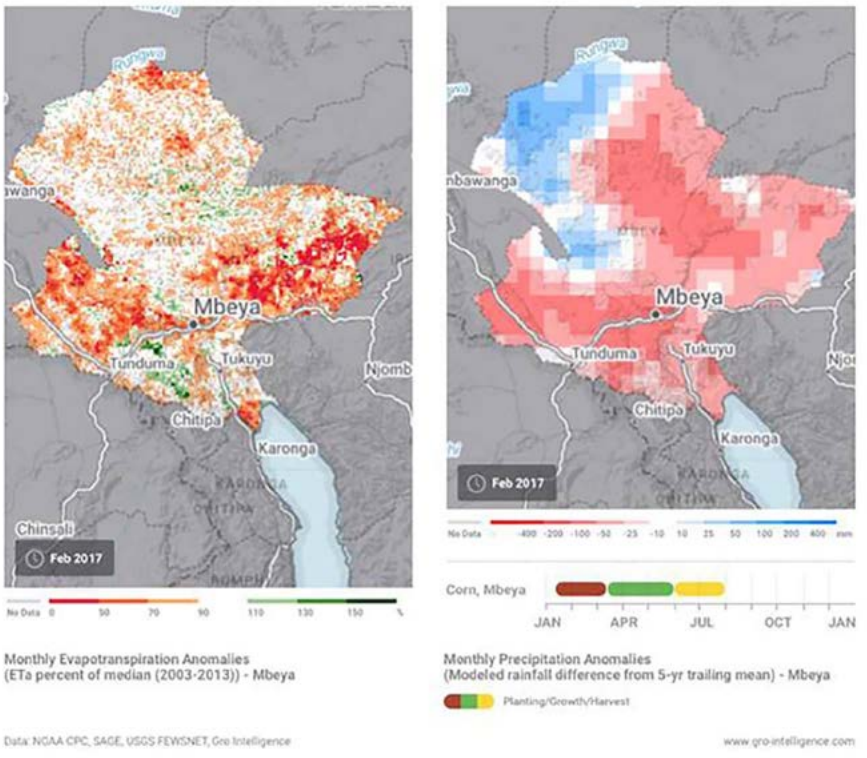
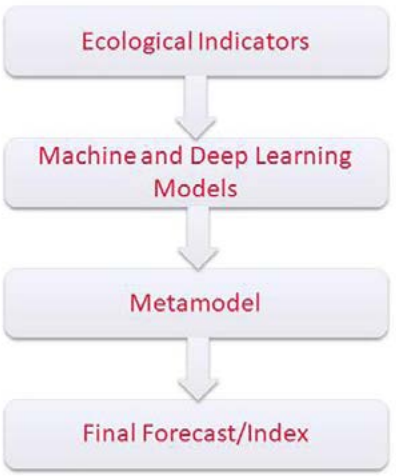


Figure 4. Mbeya, Kenya, 2017 drought

Tracking environmental indicators as they arise and evolve is critical in developing countries where subsistence farming prevails and farming families are vulnerable to even slight or short-term changes in weather or other factors that can have devastating effects. Figure 4 relates to the drought earlier this year in part of the corn belt in Kenya. We were monitoring that very closely for reasons which you'll see later on. Advances in information technology allow us to disseminate high-quality analyses of yield, drought and other parameters at much lower cost than previously possible, so we can bring the established benefits of modern modelling expertise to a hugely broader and more diverse audience.



The flow chart (right) shows our rubric for approaching the modelling task when we want to make a forecast. We feed ecological indicators into our

system and its deep learning models, build a meta-model – which is an algorithm for picking which local model to use at any given time of year in any given place – and then generate a final forecast and an index.

We built a state-of-the-art US corn-yield model using our data platform and we have been giving it away for free, which is a first, at least for a private company, as far as I know. My guess is that this is at least as high in quality as anything else that is available, and certainly a lot cheaper than earlier models, which were priced at hundreds of thousands of dollars per year simply to provide the results. Our result is posted on our website every week. We currently (August) predict a national crop yield of around 164 bushels per acre this year (Figure 5), while the USDA's current estimate for the US corn crop is around 170 bushels per acre. To a corn-futures trader, that is a very significant difference which could cause significant price-movement.

About the company

Our company started in Nairobi, so we have a lot of contacts in Africa. We've been asking for various types of information to be collected or to be assimilated somehow into our database (Table 1), and some of that is happening. The more data and the better data you have, the better the models. Ultimately, the objective is to build models that help people to make decisions.

A survey of our users late last year shows that 35% of our users are still in Africa. The number of users in North America has been rising and at 38% is now similar to the number in Africa. We also have users in Europe (16%), Asia, South America and Oceania (5% or fewer). This is a very unusual beginning for an agricultural research firm. Most of them focus on either the US market which is where the global trading hubs are located, or the European or some other developed-country market. We hope interest in Africa will remain strong, and we maintain an office in Nairobi to support that.

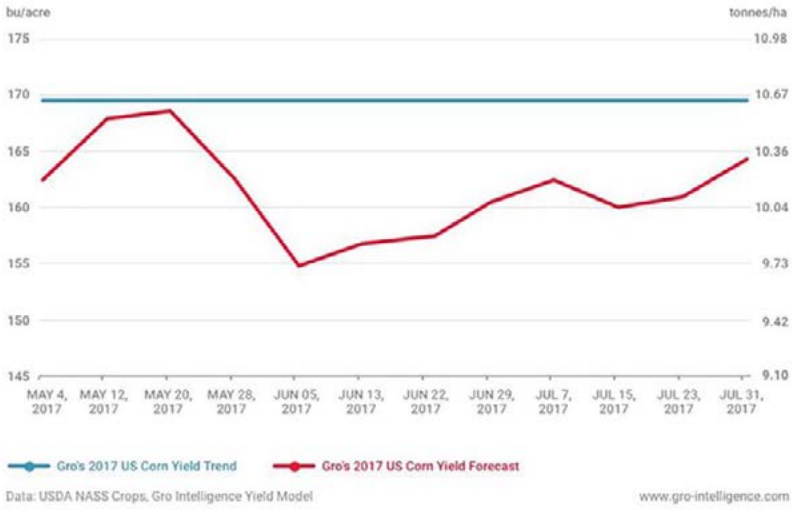


Figure 5. Gro's 2017 US corn yield forecast (lower, red, line) breaks higher

Table 1. Sample of data categories Gro believes would be critical to collect for African countries at a more frequent and detailed level

Agronomy	Production	Supply	Use	Prices	Economics
Ag equipment in use (c)	Seed production (a)	Imports (m)	Upstream – oilseed processing (m)	Inputs – fertilisers (a)	Land rent/ water rights (a)
Fertiliser use per acre (a)	Acres planted – county (a)	Stocks – province/ state level (q)	By type – maize, cornmeal (a)	Ag labour rates (a)	Total input costs (m)
Pesticide use per acre (a)	Acres harvested – county (a)	Stocks by type – grain, silage (q)	By use – seed, food, industrial (a)	Farm-gate (w)	Producer margin – by crop (a)
GMO seed use (a)	Yield – county (a)	Grain – cold storage capacity (a)	Per capita consumption (a)	Export prices (m)	Avg farm size (c)
Soil conditions (a)	Crop progress reports (m)	Grain shipments – deliveries (q)	Domestic gov't tenders (w)	Domestic freight rates (m)	Avg farm income (a)
Fallowed acres (a)	Harvest grading: ergot levels (a)	Grain handling capacity – port level (a)	Exports (m)	By-products – wholesale (d)	Avg farm debt (a)
Irrigated acres (a)	By-product = meat, feed (m)	Obsolescence – loss rates (a)	Retail expenditures (m)	Processed – retail (d)	Storage, insurance rates (m)

c = census. a = annual. m = monthly. w = weekly. d = daily. q = quarterly.

Eventually we aim to develop 'parametric risk measures' for the insurance market. These could be the basis of very precise credit and insurance products that will be critical to transforming agricultural markets around the world: for instance, by lowering the cost of capital and expanding access to credit. Better credit models can be developed by incorporating 'market risk' data into the models. Gro has access to data series that add information well beyond the existing credit history of a borrower:

- growing cycles
- climate and growing conditions
- perils (fire, flood, infestations, predation)
- prices of crops
- prices of other commodities
- national and regional programs and restrictions
- trade policies.

We all know that capital shortage is a problem for many smallholders and larger cultivation operations. Good information about risk and financial services, based on data and models that are easily accessible and understandable, should be of much greater value to smallholders than physical gadgets they buy that only work for a short time.

Fundamentally, agricultural data is like any form of critical infrastructure: it should be robust and meticulously well-maintained. While that will require effort and investment, good data, like good infrastructure, helps societies to thrive. Gro Intelligence economists, scientists and engineers are working to get more data, with more precision for more of agriculture.

Summary

In summary, by imposing structure on, and building models with, the increasingly bigger data that is available to the farm sector in Africa and elsewhere, we believe that we can bring the African agricultural community the data tools it needs to improve its own performance itself.

We believe history supports our belief that a set of solutions and methods, arrived at on the ground, locally, with the benefit of world-class data and models, will succeed well beyond any externally formulated program.

We believe that the best solution to the data problem in sub-Saharan Africa is not limited to sub-Saharan Africa: it's actually a global solution, and we believe that the free market has a significant role to play in helping people to make the decisions that only they know the various parameters of.

They can use a product, like Gro, not necessarily Gro, but something like that, to get the data that they need without us saying what they should be interested in, and I think that's of great value.

Steve Mathews is the Head of Strategy at Gro Intelligence, a software company focused on the global food and agriculture markets. Before joining Gro, Steve worked as a portfolio manager and the head of commodities research at Tudor Investment Corporation. During his tenure there, he developed extensive commodities analysis software and conducted practical study of agriculture, energy, and metals. He is a crop scout with the Pro Farmer Crop Tour each summer, and teaches agricultural hedging at the University of Memphis. Prior to finance, Steve commanded a tank company in the US Army. Steve holds a BS in Operations Research from USMA (West Point) and an MBA in Statistics from the Stern School of Business at NYU. He's currently about halfway through an MS degree in Agronomy from Iowa State University. He's also a holder of the Chartered Financial Analyst designation.

Case study: Global data, farm size and food and nutrition security

Dr Mario Herrero

CSIRO Agriculture Flagship

Abstract

Information about the global structure of agriculture and nutrient production and its diversity is essential to improve understanding of food production patterns, agricultural livelihoods, and food chains and their linkages to land use and their associated ecosystems services. We used existing spatially-explicit global datasets to estimate the production levels of crops, livestock, and aquaculture and fish products. We also estimated the production of vitamin A, vitamin B12, folate, iron, zinc, calcium, calories and protein. Furthermore, we estimated the relative contribution of farms of different sizes to the production of different agricultural commodities and associated nutrients, as well as how the diversity of food production, based on the number of different products grown per geographic pixel and distribution of products within this pixel (Shannon diversity index [H]), changes with different farm sizes. Globally, small and medium farms (≤50 ha) produce 51–77% of nearly all commodities and nutrients examined here. However, important regional differences exist. Large farms (>50 ha) dominate production in North America, South America, and Australia and New Zealand. By contrast, small farms (≤20 ha) produce more than 75% of most food commodities in sub-Saharan Africa, south-east Asia, south Asia and China. The majority of vegetables (81%), roots and tubers (72%), pulses (67%), fruits (66%), fish and livestock products (60%) and cereals (56%) are produced in diverse landscapes (H>1·5). Our results show that farm size and diversity of agricultural production vary substantially across regions and are key structural determinants of food and nutrient production that need to be considered in plans to meet social, economic and environmental targets. At the global level, both small and large farms have key roles in food and nutrition security. This analysis is crucial to design interventions that might be appropriately targeted to promote healthy diets and ecosystems in the face of population growth, urbanisation and climate change.

The study presented in this talk is the product of a truly trans-disciplinary collaboration between agricultural scientists and others. We worked with nutritionists, geographers, public health people, economists, livestock scientists and biodiversity specialists, and our aim was to try to map farm sizes around the world. This is a fundamental piece of information that is needed for a range of uses: for achieving the Sustainable Development Goals (SDGs) for example.

Until last year, we did not know what percentage of types of foodstuffs was really produced by smallholders in different countries. Yet that is a question we regularly get asked in various forms by donor agencies to guide their strategic

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

Figure 1. Satellite images of farmland in West Iowa (top left), France (top right), and northern India (left).

projects: for example, "What is the percentage of livestock coming from the smallholder sector?".

We started comparing farmland in different regions – for instance, in West Iowa, and in France and in northern India (Figure 1) – and asking ourselves: Is there any difference in the quality of the outputs from these different size farms? Do we get better ecosystem services? Do we get more nutrition coming out of fields like this? Do we get more risk, more resilience, etcetera? These are crucial questions if we really believe in the sustainability of our planet and in actually trying to create viable futures for smallholders in the developing world.

Since we began this study, the agenda has changed. Now we're talking about nutritional security. Kilojoules or calories produced per unit of land are simply not enough. Now we need to be very much more sophisticated in how we talk about the produce coming out of farming systems. Donors need this kind of information continually to make allocation decisions, and to understand how situations are changing in the smallholder sector. And for the SDGs we do not know enough about the sustainability of our planet if we do not understand the structure of agriculture.

The structure of production needs to be incorporated into global integrated assessment. It is not good enough at this stage to know that, for instance, the projections for China say it will be able to produce two-thirds more cereal. Instead, because of ethical considerations, what matters is who is going to produce this data, and what will be the impacts of the various schemes for producing the food – on the environment, or on livelihoods, on trade, etcetera?

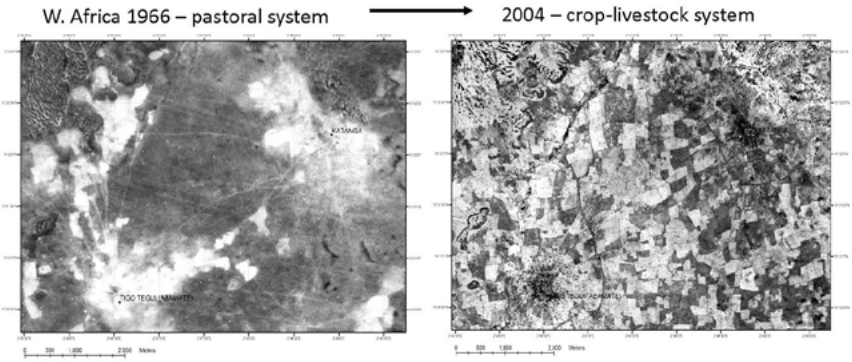


Figure 2. What role for smallholders in the future? Systems and livelihoods are in transition: the system is moving. *Source:* Herrero et al. 2012.

Obviously, there is also a big focus on linking agriculture with nutrition and health, which is strongly related to the current discourse around sustainable diets. Humanity really needs to try to eat better, so as to reduce the double burden of poor nutrition and the potential for very big health costs, especially as populations age.

However, the structure of production is constantly changing. All we can do is provide a snapshot at a particular moment, which is what my team has done. In reality there is monumental change happening in smallholder systems. Figure 2 illustrates a typical transformation seen in many African countries: changing from a pastoral region to one dominated by mixed crop–livestock systems in 40 years. This matters because, when we consider, for example, the roughly 20-year lag in technology-adoption in smallholder systems, it means that new technology is obsolete before it has been widely taken up – if the technology is being developed in the traditional way. So understanding systems-change is fundamental, and it is also fundamental for looking at the competitiveness of smallholder sectors.

Increasing importance for smallholder systems

In her Sir John Crawford Memorial Address yesterday, Dr Sibanda showed us that smallholder systems can become even more important as the agenda moves towards nutritional security. I agree with that. Nutritional diversity, including growing many things in little plots, can be very important. Nutritional diversity is key to sustainable nutritious diets, and sustainable profitable ecosystems. Although many diets meet the requirement for kilojoule or calorie availability, we are learning our micronutrient intake is dependent on the combinations of food we eat – and produce (Figure 3).

There is so much we do not know yet about nutrition. People tell me I am a romantic to value small systems, because farming is becoming consolidated into large farms, but I question whether that is the best way to go. Imagine a big pest in maize in the fields of Kansas; imagine how those farmers are going to manage risk. Do we know enough about use of resources, about emissions (Figure 4),

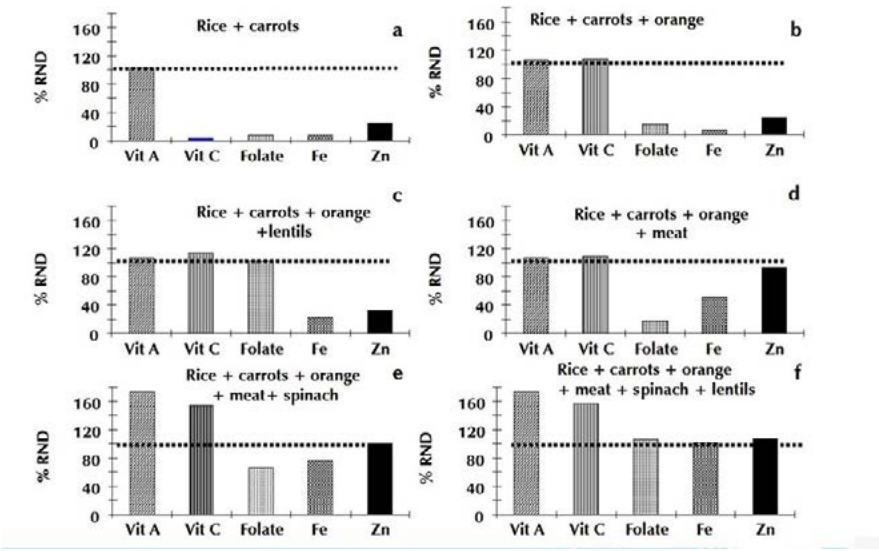


Figure 3. Nutritional diversity matters. *Source:* Oyarzun et al. 2001.

about income and employment opportunities for people? No, there are still too many questions.

Classifying farm sizes is an important initiative that can start opening this debate much more effectively. Also, from the sustainability perspective, what we grow will matter tremendously in these farms.

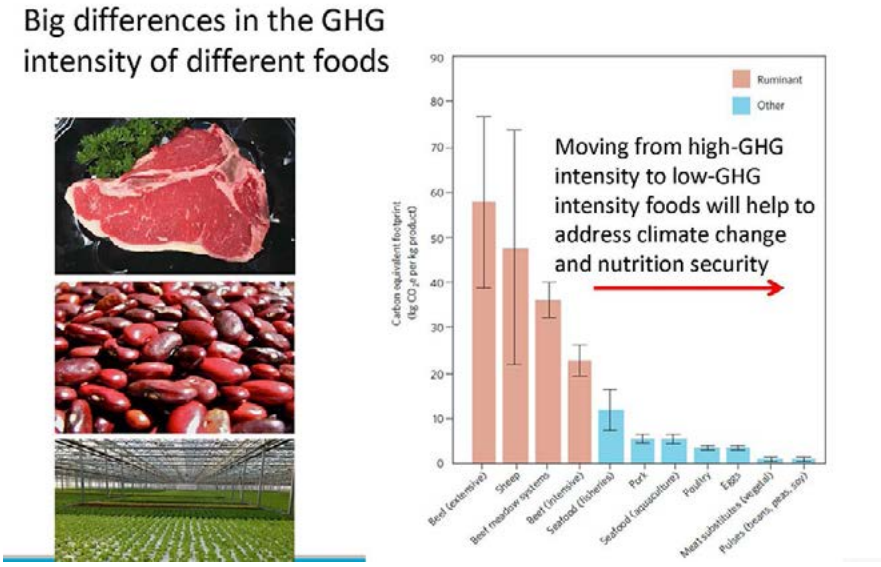


Figure 4. Foods differ in the greenhouse gases emitted during their production. *Source:* Ripple et al. 2014.

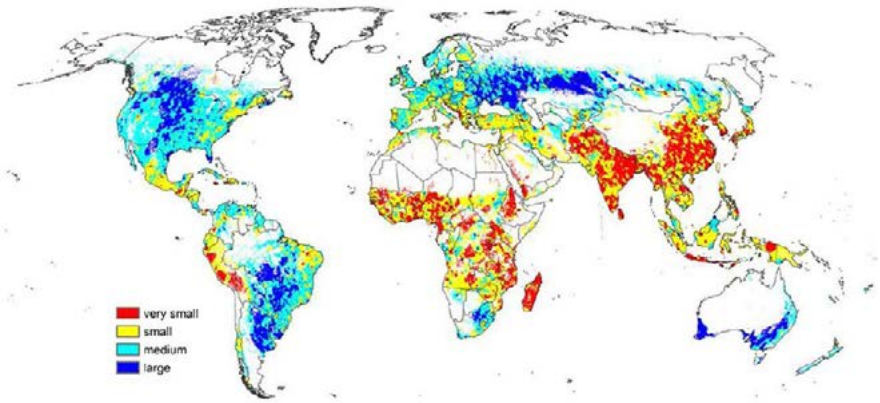


Figure 5. A global map of field size, derived by crowd sourcing and machine learning.
Source: Fritz et al. 2015.

Study methods

We started with a global map of field sizes (Figure 5) that we produced via a crowd-sourcing campaign that we then linked to satellite data (as in Figure 1). Then we applied machine-learning algorithms to estimate the plot sizes that were likely to be most important in these places. Then, using a range of optimisation techniques, we linked those to the farm-size distributions that are recorded in censuses from different countries, using 160 sets of census data. Figure 6 shows an example for Burkina Faso. As a last step we collected global spatial data on crops, livestock and fish: 42 crops from EarthStat, 7 livestock products (Herrero et al. 2013), 11 fish products (Watson 2017) – imagine all these layers on top of the data on farm sizes – and then we calculated the amounts of different nutrients that these crops and livestock products and fish could provide (Figure 7).

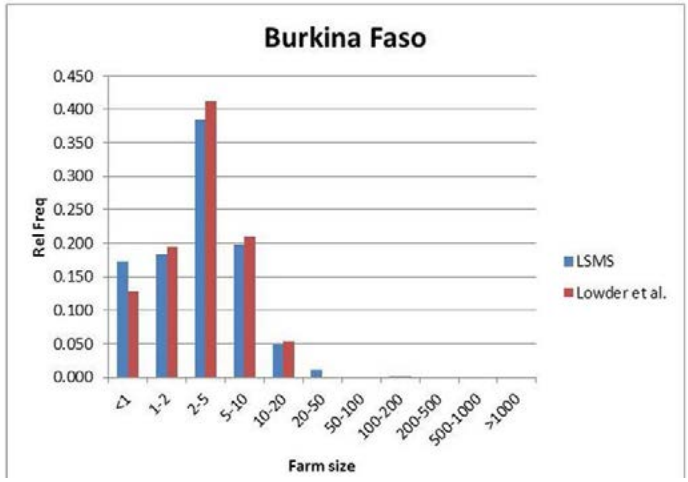


Figure 6. Farm size distributions, Burkina Faso.
Sources: Lowder et al. (2014), data from 1993; recent LSMS data, Frelat et al. (2016).

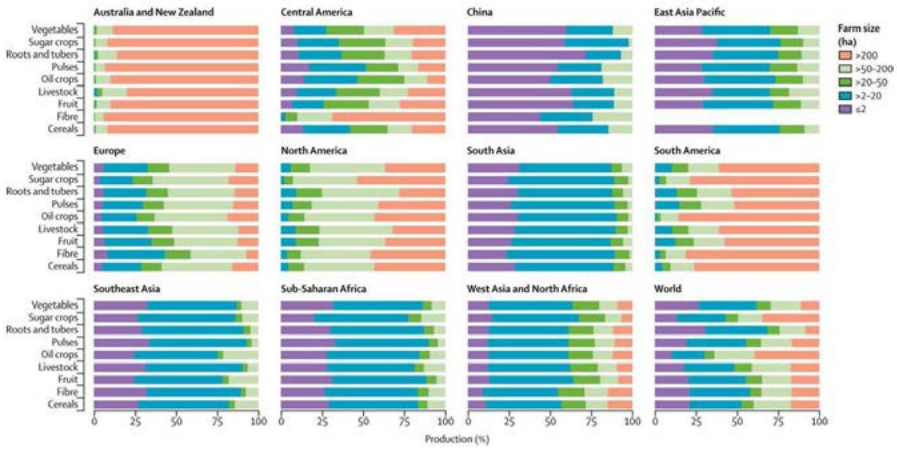


Figure 7. Small & medium farms produce 50–75% of the world's food. Horizontal axis = % of production; vertical axis = food type. Purple = farms <2 ha. Blue = farms 2–20 ha. *Source:* Herrero et al. 2017.

Figure 7 shows that, even if you take a global perspective, small and medium farms produce between 50 and 75 per cent of the world's food. This pattern is also similar for nutrients, apart from what is actually calories and also some of the oils that we tested (Figure 8).

We also looked at the diversity of agriculture, taking biodiversity indexes. In Figure 9, the deeper the purple the more diverse the production, with percentage of production on the horizontal axis from 0 to 100 left–right. The figure shows that more diverse landscapes are actually producing more food. You can see Europe has much more diverse production than the US. We also found that as farm size increases the agricultural diversity decreases.

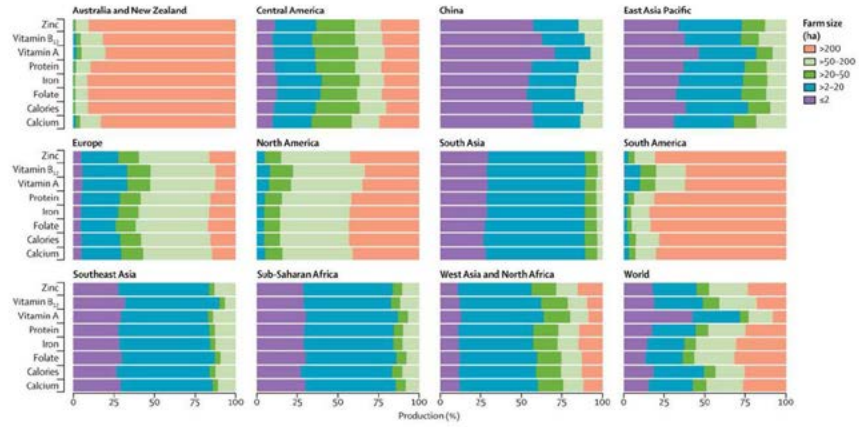


Figure 8. Nutrient production forms a similar pattern. Horizontal axis = % of production; vertical axis = nutrients. Purple = farms <2 ha. Blue = farms 2–20 ha. *Source:* Herrero et al. 2017.

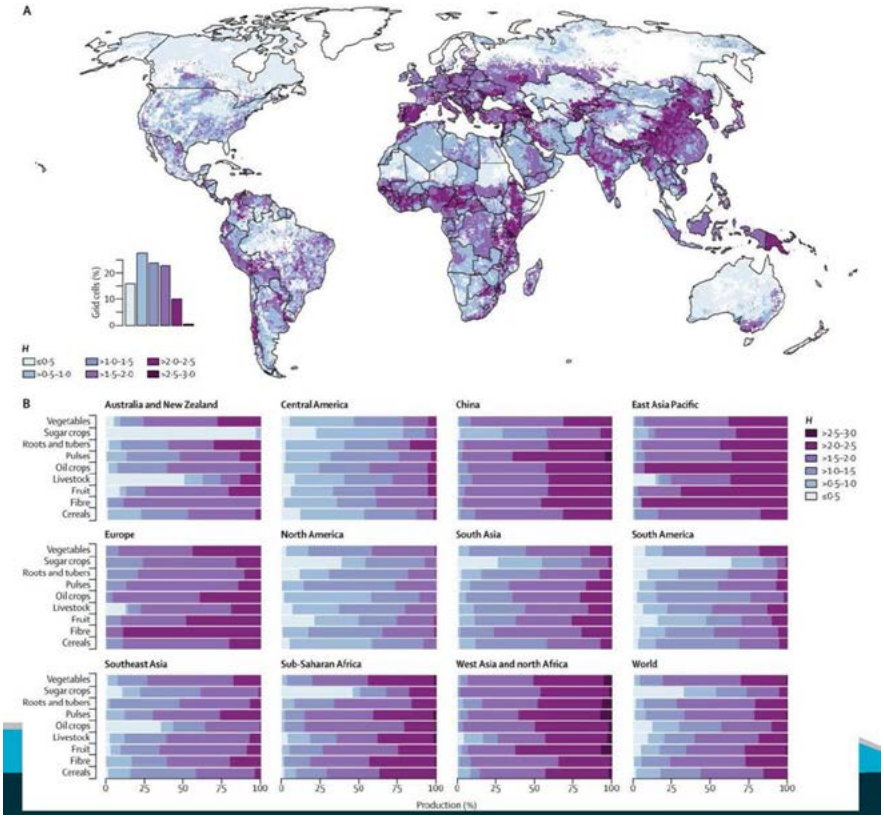


Figure 9. More diverse landscapes produce more food.
Horizontal axis = % of production; vertical axis = food type. *Source:* Herrero et al. 2017.

This is a crucial element, because we are trying to promote sustainable intensification. Sustainability is an aspect that is sometimes overlooked as food producers focus on a few cereals and a few crops that are easy to cultivate but that are actually diminishing our capacity to produce a wide variety of nutrients. Figure 10 shows nutrient production in relation to landcape diversity.

Uses of data, new research areas, and a recommendation

How can we promote sustainable intensification without losing diversity? The answer to that question needs to be central to how smallholder sectors are considered. The information we are collecting is the first that shows the relation between diverse landscapes and the production of a diversity of nutrients. Certainly, the patterns of these graphs differ greatly depending on where you are, but looking at the global picture we can see that we should try not to lose the great diversity associated with smallholdings, as Dr Sibanda beautifully presented with her account of her lived experience.

We released this data in April 2017, and we have seen an interesting response from the research community. The people working on the Global Burden of

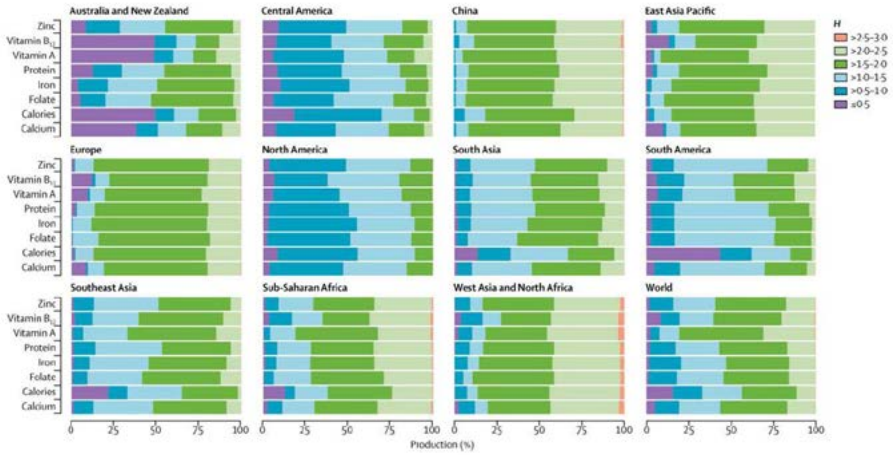


Figure 10. More diverse landscapes produce more nutrients.
Horizontal axis = % of production; vertical axis = nutrients.
Orange and green indicate larger amounts. *Source:* Herrero et al. 2017.

Disease took up the information on nutrients immediately, so as to link it to epidemiological data on stunting in children, for example, leading to potentially more trans-disciplinary work. The data has also been used in the Global Nutrition Report and by the EAT-Lancet Commission. Biodiversity research teams are interested to examine the data and see if places that are diverse in food production are better at maintaining ecosystem services and biodiversity, and if they are also better from a land perspective and so on. These are the kinds of new linkages that are going to be needed to meet, for example, the Sustainable Development Goals.

Finally, we should not let the default situation be that the market leads to consolidation of farms. There needs to be policy influence on the structure of farming. We need mechanisms through research and policy to actually understand and better shape the future in terms of farm structures, recognising that they seem to be central to how we will produce the necessary nutrients that we are going to need to feed the world.

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Mario Herrero is a Chief Research Scientist and Office of the Chief Executive Science Leader in CSIRO's Agriculture Flagship. He has more than 20 years experience working on strategic agricultural R4D projects in Africa, Latin America, Asia and Europe. Before coming to Australia in February 2013, he spent 12 years in Kenya, leading the Sustainable Livestock Futures and Climate Change programs and the Targeting Pro-Poor Interventions team at the International Livestock Research Institute. A known team-player, with an extensive network of partners and donors, he works in the areas of agriculture, food security and global change, targeting agricultural investments in the developing world, sustainable development pathways for smallholder systems, ex-ante impact assessment, climate change (impacts, adaptation and mitigation), development of scenarios of livelihoods and nutrition futures, multi-scale integrated assessment, and others. He has experience working at different scales, from the animal and farm level to the country, regional and global levels. He has coordinated several global and regional integrated assessments initiatives such as the African Livestock Futures Report for the Office of the UN Special Representative on Food Security, and the CGIAR global assessment of food production systems, ecosystems services and human well-being to 2030. He has also contributed to numerous international assessments such as the IPCC 4th and 5th Assessment Reports, 2010 World Development Report, the 2007/2008 Human Development Report and the 2007 Comprehensive Assessment of Water Management in Agriculture. He regularly participates in international committees such as IPCC's Working Group 3 (Mitigation) and the IPCC Task Force on Greenhouse Gas Emissions, and has served in several donor and science advisory committees on agriculture, livestock and the environment. He has published more than 300 fully refereed papers, book chapters and reports in his areas of expertise. He is currently on the editorial boards of *Agricultural Systems* (Elsevier), *Global Food Security* (Elsevier), *Agriculture and Food Security* (BioMed Central) and *Tropical Grasslands*, and has been a guest editor for the *Proceedings of the National Academy of Sciences* journal (*PNAS*). He has also supervised over 60 academic theses on different aspects of tropical agricultural production systems, and has recently become a Honorary Professor of Agriculture and Food Systems at the University of Queensland, Australia.

Case study: Genebank mining with FIGS, the Focused Identification of Germplasm Strategy

Dr Ken Street

International Center for Agricultural Research in the Dry Areas (ICARDA)

Abstract

As the world moves forward into an uncertain future our agro-ecosystems will come under increasing pressure, threatening our food security. In fact, climate change, dwindling water supplies, rising energy costs, the emergence of new pests and diseases, loss of arable land and population growth mean that our crop plants will need to yield more on less land, with fewer inputs under increasingly harsh conditions. For this reason, plant breeders will be forced to mine global plant genetic resources collections for variation that can be used to future-proof our crop plants. However, the genetic resources collections are large and we cannot afford to evaluate every accession in a collection as we hunt for desirable traits. The Focused Identification of Germplasm Strategy (FIGS) was developed to help unlock the variation in genebanks and make it more accessible to the plant breeding community. This paper explains how FIGS works and gives examples of how rare traits have been uncovered by using the technology.

In the course of my work at ICARDA I would have spent something like 30,000 km bumping around in old Russian 4-wheel-drives on collection missions. It was often rough going, and I frequently wondered if the journey would be worthwhile! That is what led me to the scientific aspect of my work: namely, to find better ways to use plant genetic resources from our genebanks.

The context for this case study is the serious situation facing our agro-ecosystems. We are going to have to grow more food on less land, with fewer inputs under harsher conditions as we move forward into the future. Therefore, without question, we are going to have to redefine the capabilities of our crop plants. That means we shall need a great deal of innovative plant breeding, very soon, and until the 'fabled' gene editing technology becomes available we are going to have to rely on the genetic diversity within the accessible gene pools.

Luckily, because there have been many plant collection missions in the past, there is already a great deal of useful diversity within the genebank system. The genebank shown in Figure 1 is the ICARDA genebank. It is very diverse, and its diversity is backed up in facilities like the one at Svalbard.

Challenges of finding the traits you need

It is excellent that the genebanks have captured so much diversity, but there is also a problem with that. Imagine you are a plant breeder and you are

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

Figure 1. The genebank at ICARDA (main) and the Svalbard vault (top left).
(ICARDA = International Center for Agricultural Research in the Dry Areas)

breeding for a rare trait, a rare adaptation, such as frost resistance during the reproductive phase. You have only enough resources to screen a couple of hundred accessions: not thousands; just a couple of hundred. However, the gene pool you are working with contains something like 315,000 accessions. How can you choose the accessions that will be useful?

We need rational ways of digging into these collections of genetic resources so we can pull out the useful variation. And that is where the Focused Identification of Germplasm Strategy (FIGS) becomes important. That is what FIGS does.

FIGS is user-driven. The user's request for a particular trait comes to the genebank, and we then attempt to put together a small set comprising useful germplasm. The selection process is based on some very well established principles – Darwinian Natural Selection. In a nutshell, to find a particular adaptive trait, FIGS searches collections from the environments where there is likely to have been selection pressure for that trait. It is very straightforward, but genebanks did not use this approach until quite recently.

Linking traits to selection pressures

There are lots of examples of eco-geographic variation for adaptive traits. One I have found really interesting is that apparently human nose shape is connected to the environments from which our ancestors came: the narrower the nose the colder the environment. These connections are thought to apply to plants as well, but do they apply in practice?

To answer that, I will now explain how FIGS works, in general terms without very much detail. Figure 2 shows the initial very simple filtering stage. The staff member looks at the environmental conditions at the collection sites from which the material in the genebank has come, and applies a filter to these parameters and importance.

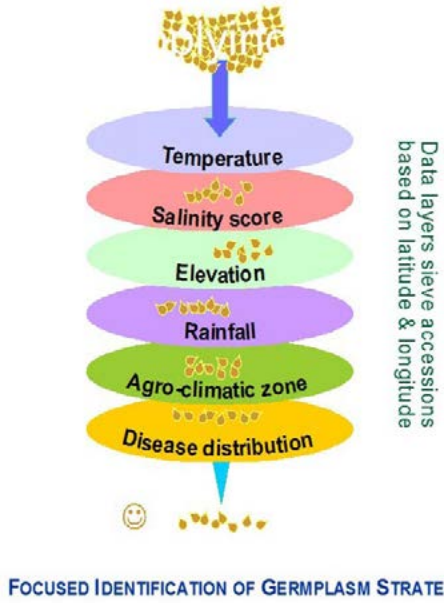


Figure 2. Diagram of the FIGS simple filtering method.

Figure 3. The Sunn Pest *Eurygaster integriceps* (10–12 mm long).

A good example, the Sunn Pest, shows how science does not have to be complicated to solve a problem; it can be quite simple. The Sunn Pest (Figure 3) devastates smallholders' plots right across the northern hemisphere. It is not a problem here in Australia ... yet. Dr Mustapha El-Bouhssini, of the ICARDA Entomology unit, had screened literally thousands of accessions of hexaploid wheat looking for resistance and found nothing. When he heard about FIGS he became really excited and asked us to put a set together.

The process we used to select a set is shown in Figure 4. First, we excluded any collection sites where there had been no record in the past of some pest being a problem; second, we excluded dry environments and very cold environments during winter time, the idea being that we wanted to select sites that would favour a high pest load.

When we presented Mustapha with the material we had assembled, he found ten sources of resistance in a small set size. It is a really important finding,

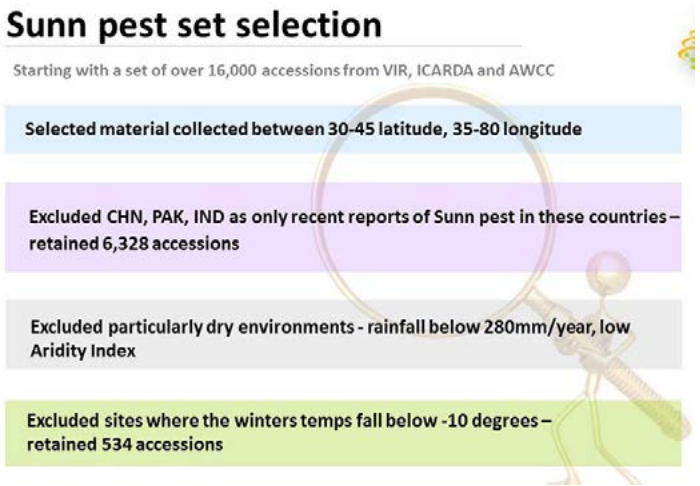
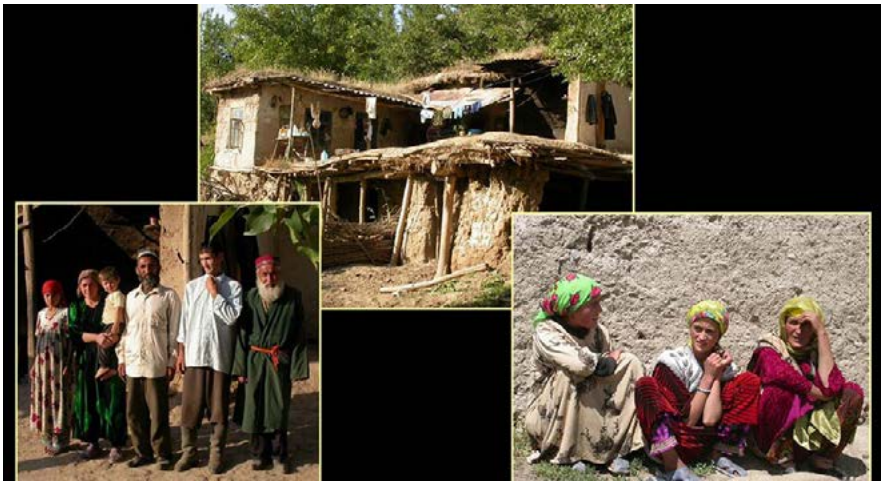


Figure 4. Example to illustrate the FIGS selection process.

Above & below: Collection trips to Tajikistan (below) and Afghanistan finding 2 landrace accessions identified as resistant at juvenile stage and 8 landrace accessions (Afghanistan).



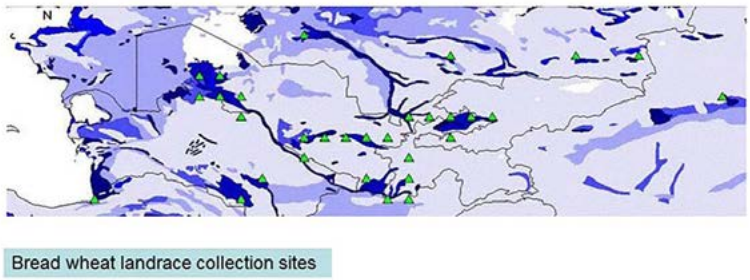


Figure 5. Map used in screening for salinity tolerance in bread-wheat landraces. The FIGS subset was chosen by mapping collection sites over salinity probabilities.

particularly for the people that ICARDA services, the smallholders. The trait is now in the breeding program and apparently varieties will be released shortly.

That example ties back to those collection projects in the old Russian 4WDs (photos previous page). Two of those sources of resistance were found in samples from a collection mission in Tajikistan in a little village that time had forgotten. These people were custodians of really important genetic variation – not just resistance to Sunn Pest but also resistance to the Syrian biotype of the Russian wheat aphid, a very virulent version, as well as to a suite of diseases.

More examples: salinity tolerance and drought tolerance

The map above (Figure 5) shows the probability of encountering saline soils: the darker the colour the higher the probability. We mapped sites where wheat had been collected over this base map and on that basis we chose a subset of bread-wheat accessions to be tested for salinity tolerance by measuring plant uptake. When we measured the salt taken into the leaves of the subset after 10 days, compared to a core set of accessions, we found that 21% of the subset were resistant to salt uptake compared to only 3% of the core set.

In another example, with Faba Bean, we used the FIGS method to put together two sets, looking for major gene traits associated with drought tolerance. As shown in Figure 6, the root system is obviously adapted to dry environments, but those tests used long-term monthly averages to define the climatic parameters.

We wanted to explore the growing season a bit more deeply and refine the FIGS technology. So (using 'big data'), we constructed a series of GIS surfaces for a set of parameters (Figure 7) to construct long-term daily average surfaces. It involved generating over 100,000 surfaces, for the whole of the Northern Hemisphere, wherever our major crops developed – over 200 terabytes of data. From that we could construct, for every single collection site, or every single pixel on the map in Figure 8, a 'probable onset of growing period' for the crop in question. From that we could estimate the growth cycle of the crop, and then analyse the specific stages of crop development where the trait of origin is likely to be selected for. In this case, in the growing season, in the heading phase, we would apply our filter for frost tolerance, for example. That is what we are doing in a GRDC project at the moment.

As a result of using that slightly advanced FIGS methodology we have found useful sources of resistance for a whole suite of characters, which is very helpful to our growers of course.

Figure 6. FIGS selection for drought tolerance in Faba Bean.

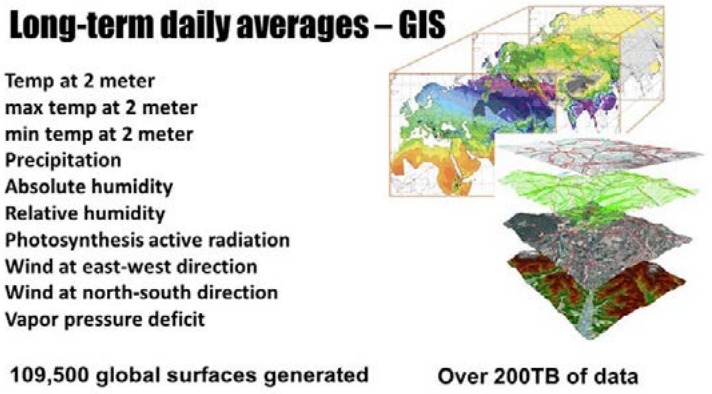


Figure 7. Using 'big data' we generated long-term daily (rather than monthly) averages of climatic parameters

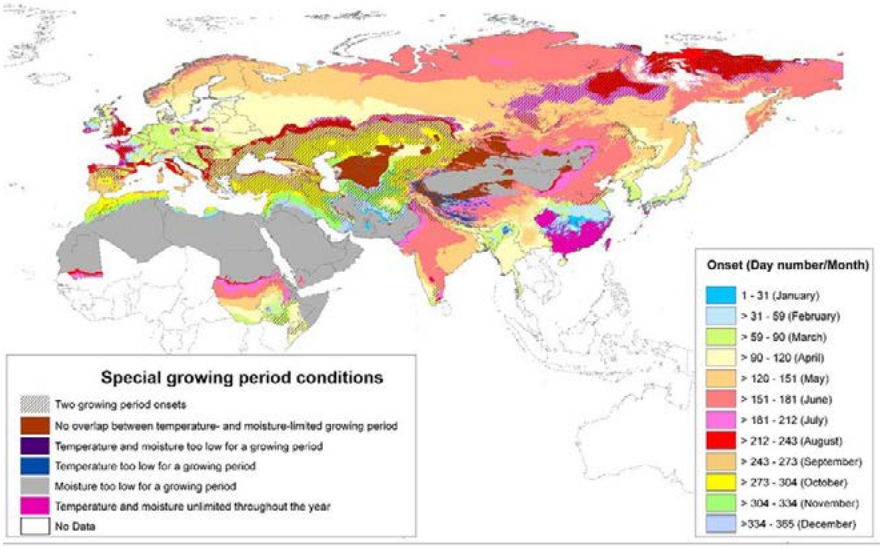


Figure 8. Map showing onset of growing periods limited by temperature and moisture.

More complicated FIGS

As well as using the simple filtering method in FIGS, we are also able to evaluate collection site data with multiple trait states, and we are developing statistical non-linear models to capture a relationship between the trait state and the environment of origin, using machine-learning. The outcome is a model that can predict, or discriminate between, the different trait states. Given genebank data and the collection site data, it will generate a map of the likelihood of finding the traits we want (Figure 9 for example). We have published this in various journals.

In FIGS in the future we hope to incorporate molecular data into the process. We have very large quantities of molecular data. Also, we want to improve the

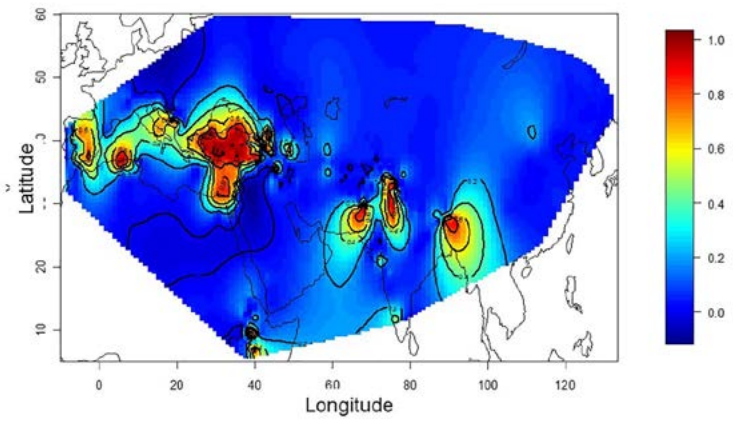


Figure 9. A typical output from FIGS predictivie modelling: areas where resistance is likely to occur are shown in dark red.

Figure 10. Acknowledgements

accuracy of the onset data, and, most important, we want to develop a software application so anyone can do this process.

Acknowledgements

GRDC has backed its vision and given wonderful support over the years. ACIAR supported the collection missions. Michael Mackay (centre of Figure 10) came up with the concept of FIGS in the first place. This work has been done at ICARDA, and I also want to acknowledge the scientists currently working on FIGS.

Further reading

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Dr Ken Street is a genetic resources scientist who has spent most of his scientific career involved in the collection and conservation of cereal and food legume agro-biodiversity. Based at the ICARDA genebank, situated in Aleppo Syria, Dr Street was responsible for undertaking numerous plant collection missions throughout Central and West Asia and the trans-Caucasus. In addition to his plant collecting missions, Dr Street was also involved in research aimed at improving the efficiency with which we mine genetic resource collections for useful traits. The outcome of this collaborative work was the Focused Identification of Germplasm Strategy (FIGS) that has been successfully deployed to discover rare crop traits that will have a positive impact in farmers' fields.

Q&A: Uses and challenges of 'big data' for agricultural development

Chair: Dr Kim Ritman

Australian Chief Plant Protection Officer and Chief Agricultural Scientist

Steve Mathews, Mario Herrero and Ken Street in the Q&A for session 2.

Q: Frances Hoyle, *The University of Western Australia*

One observation and one question. Observation: I'd like to draw a parallel between Dr Sibanda's presentation yesterday and her emphasis on her grandmother and gender, and 'big data' this morning where gender has been rather obviously absent. So what is the role of gender in 'big data' for smallholders, not just for the small guys, but also for the small women? What is the role of gender knowledge in genebanks? What's the role of women in Ghana in relation to drought insurance? And what do we know about users who have apps, both men and women, who try to find out about how to buy trades, market opportunities and weather events? I would be delighted to hear from you, thank you.

A: Steve Mathews

Honestly, it's something that I haven't thought about a lot. We market a product that is available to everyone who is interested in using it, so in terms of different treatments of the genders with regard to 'big data', it's a problem that we haven't really addressed, honestly.

A: Mario Herrero

Yes, the role of women in 'big data' – enormous, I think, and especially because if you look at smallholder systems the vast majority of the poorest of the

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

smallholders would actually be female-headed households. So just from that perspective, not in the project that I spoke about but in other projects, we've been creating something we are calling 'data rescue exercises of farming systems data'. This is allowing us to do much better analyses of the roles of women, and also much better analysis of how to target technologies so that when you move to the more formal markets they're not swamped by the men, for example, which is something that often happens in parts of Africa. And Dr Sibanda also mentioned something else that is really important: we know that female-headed households have better nutrition outcomes for kids and for the family because they tend to use the resources differently. So people working in the health sector are trying to create the link between women farmers and the diversity of what is produced and the health metrics. To me it seems obvious that when we can involve women enumerators and women doing the analysis, the perspective will also be slightly different to what we otherwise see. It also happens when there are women scientists in the field, and gladly I see here a lot of young females, probably very eager to go and start engaging with these people.

Q: John Muir, *currently consulting for Oxfam in Cambodia*

My work involves conflicting roles in Cambodia, as a consultant in Oxfam's resilience program for small landholders, and also consulting on large-scale concessional land. Alongside that I've come across articles that report Monsanto is about to buy ag data and then sell it to everyone – is that true or not?

A: Ken Street

I have not heard of that. Clearly, Monsanto's a big player, but it is just another one of the big players among many.

Q: Shumaila Arif, *Charles Sturt University*

My question is for Mario Herrero. Do you think that agricultural diversity is traded off with biosecurity? So when we are addressing smallholder farmers should we address biosecurity first and then go for mixed farming?

A: Mario Herrero

Well, I think there is less of a trade-off, because if you have a large range of species you can deal with risk and with biosecurity risks much more effectively than if you have only one or two crops, which is the more common situation. And if you are implementing integrated pest management in mixed systems, well that actually deals with biosecurity issues pretty well in many cases.

Q: Peter Wynn, *Charles Sturt University*

We've talked about patterns of food production, but one of the major limitations of the world is the distribution of food. How can we best map – and I address the question to Steve and Mario – how can we best map the distribution patterns of food throughout the world so that we can identify the bottlenecks that limit our ability to deliver food to those who really need it, because that, as I see it, is a major issue.

A: Steve Mathews

The land is trickier to model than production, there's no question about that. We're working hard on it, and there is data out there. It's not always easy to get; it's in a variety of formats involving point-of-sale systems, and I realise I'm talking about developed markets when I say that. But that sort of technology is penetrating down into the less-developed markets and becoming more available. And also, governments are collecting information on that stuff. But you have a good point: our grasp of distribution and demand is not as good as our grasp of supply and production.

A: Mario Herrero

Can I add to that? There are a couple of products of bilateral trade. They're not very spatially explicit, but at least you would have trade flows between countries of different commodities and different food products as well, even processed food and so on. So, for example, the University of Kassel will have one, and the University of Vienna would have another one that is very widely used by the integrated assessment community.

Q: Joseph Macharia, *Queensland University of Technology*

My question is to Mario. There is a trend of declining numbers of smallholders according to the latest studies, and there is now the emerging medium-holder, who holds around five acres. Do you think these farmers are the best suited to adapt to these technologies, given that there are also so many groups using social media to share knowledge and get information? Medium-scale farmers, where there are declining numbers of smallholder farmers, especially in some countries in Africa such as Zambia, Ghana, Malawi and others?

A: Mario Herrero

Yes, I think that is a really important target group and I think it's a target group that is probably emerging also for most of the donors. We are finding that as farm-size shrinks in these countries, there are not enough incentives among the really small farmers (of 2 hectares or so) to actually invest in the land, so they end up having to do a range of other things. Yes I would agree with you that the engine of growth in the smallholder sector would be farmers slightly bigger than the typical 2-hectare smallholder that you would see in East Africa and similar regions – bigger being holdings in the range of around 5–10 hectares.

Q: Sam Coggins, *Agricultural Science student, The University of Sydney*

G'day. I specialise in data analysis. Steve mentioned in his presentation about the limitations of data and that it's often a bit of a mess, it's not uniform, or it might not be accurate or precise, and that's obviously a limitation when you're trying to map farm-size or find useful germplasm. I was wondering what your key strategies are for overcoming those limitations and making unreliable data useful?

A: Steve Mathews

In our case, it's just a lot of hard work. We have a philosophy of not actually changing data that has come from a third source, or a second source, depending how you look at it. Instead we deal with the source to get it corrected there,

so that there aren't different versions of that data being propagated around the world. It takes time and it takes a lot of effort. In theory, that is what our business is about, to some extent.

A: Ken Street

In our case with FIGS, the really difficult thing is to get accurate latitudes and longitudes for the collection sites; there's a lot of fuzziness there. So what we would do is give a metric to what we think the accuracy is and take that into account when we're building our sets.

A: Mario Herrero

From the agricultural data that we use, I can tell you that there's a fair bit of science but there's also a fair bit of 'black arts' that we use in putting this together, in making all the necessary judgements of what is good data for certain parts and so on. I think there's a real missed opportunity, and I hope that Andy will talk about this later, in that we always have to go around chasing people, or sometimes we find data serendipitously. It would be really nice if we had this well consolidated in proper spaces, well maintained, etcetera. A lot of effort goes into the cleaning and the maintaining of the data, and if these products were already in certain repositories, it would be really useful actually.

A: Steve Mathews

One thing I'd like to add, is that I know of a lot of small firms that are doing their own cleaning and organising of data – and they're siloed. They keep the work secret from each other because they see it as a competitive advantage. What a waste of time! If there was a group like GODAN or Gro or similar that did this, where it's done once and it's reliable, that would be a huge help to a lot of people.

Q: Sophie Lamond, *The University of Melbourne*

That's a good segue to my question. I suppose the projects that you've all presented are reasonably open and they are talking to Commonwealth resources. But we need to be realistic – data is a tradeable commodity and there are a lot of people for whom their individual data can go into something open and good, or it can become a tradeable competitive advantage for profit. How are we setting about empowering smallholder farmers to understand issues about their personal advocacy, privacy and the power that they actually have with their own data, and how do we have these conversations?

A: Steve Mathews

I've been involved in a lot of discussions about how to get data from smallholders in a reliable way, and my answer, and other people's as well, has frequently been, "Why don't you pay them?". And people act as if that's a terrible idea and it's somehow morally wrong. I don't understand that. You're asking people for something of value and, in my opinion, they should get something of value in return. Frankly, the value could be quite small and yet still be appreciated and a reliable way of getting decent data. Clearly some people would provide poor data, but it would washout in the mass of data that you accumulated.

A: Ken Street

Can I make a comment – ICARDA do a lot of surveys for data and they stayed away from paying people for data, because people will construct data depending on what they think you want.

A: Steve Mathews

That's not an issue. But with the free model you're trying to get data from people who have better things to do. And you're talking about not just a survey, you're talking about collecting it every week for the next 20 years, or something like that. They're just not going to keep up with it, and you end up with abandoned projects.

A: Mario Herrero

I think there are two things about this. On one hand, yes, data are very valuable, but some of us, especially when working with public funds, feel we need to – and sometimes we are contractually obliged to – provide the data and to make it open source. For some groups you work with now, such as the CG System and many other donors including the Gates and others, that is now standard. But from my perspective, what I've found is that the sharing of the data, even from a non-profit perspective, is what raises even more money for groups like mine, because I'm seen as the good guy always giving data out. What happens? I'm always included in new projects, for example if there is a new grant, a new paper – and that will lead to other grants, etcetera, new initiatives. I think without a doubt that open data is a much better solution. When you are trying to protect it, you will find that three people are after your data ... but thousands of people will use the open data, and your protected data will become obsolete in seconds. By the way things are going at the moment, I don't think that we're in a position to be able to hold onto information forever, because its value is changing constantly. It's getting a lot cheaper to do that analysis that I presented now we've done another campaign with five times the data, the crowd-sourced data. Now we can go and repeat it and it was done in two months. Data becomes obsolete very quickly at the moment.

Q: Wendy Umberger, *Centre for Global Food & Resources, Adelaide*

I am an ag-economist and we are involved in collecting data at household level and also using time-series data. So I want to throw out a question to any of you who can answer it, relevant to the previous questions. I don't believe data does become obsolete when you're looking at household-level data, and particularly when we're trying to look more at the connection between agriculture and nutrition at the household level. Yet the data at the household level, the nutrition data, is often using big balance sheet data that's a mess because of trade issues. Big assumptions are being made on the basis of data that's really quite poor. Public sector funds, across the board – the USDA was mentioned this morning and we see it in Australia – they're really pulling back in terms of collecting even household-level data. This is a policy conference, and I'd really to like hear some comment on how we can get governments to invest again in that household data at the farm level, and to improve the quality. Because to do good time-series analysis we need good quality continuous data sets and those

are falling apart, even in places like Australia and the US. The same goes for the data sets we have for the countries that we're all working in. So I'd love some comment on that, from a policy standpoint.

A: Mario Herrero

I completely agree with you and perhaps I shouldn't have said that data become 'obsolete' for current analysis, because definitely panel data are essential. Probably the best example that we have now is the World Bank LSMS data (Living Standards Measurement Study) for smallholders. It's not perfect but we need to try to come up with a model that actually does what the LSMS group are doing for a broader range of countries. Yeah, it's very expensive, but to do this systematically ... I think it's the only way to be able to get much better analysis and much better ground-truthing of the kinds of models that we are actually trying to implement.

And also, with the LSMS data, we find it needs to be open to more disciplines, because you start looking at it and then somebody from the livestock science area notes that they didn't collect, say, two particular variables, and those might have been two variables that would have really enhanced the value of the information, and so on. So even organising what kind of data we're going to need, and perhaps framing something around the kind of household data that we need for that if we're serious about the SDGs ... still the LSMS probably doesn't have everything that we need. Ideally we'd be taking the big initiatives, taking the big goals to actually drive our data processes, instead of trying to retrofit just what we have, and for example trying to use it to monitor progress towards the SDGs. There would have to be some kind of international panel to organise this for sure.

A: Steve Mathews

I'd like to suggest an alternative to that idea, which is obviously a great idea. What's going on in the US right now is instructive: namely that not only are our existing programs being cut back – in other words data is not being collected in quite the way it used to be – but also that existing data sets are being obscured from view, which is unbelievable! I think there's a lesson to be taken from this, and that is that policy is subject to change, and any solution that relies on policy-makers to maintain a constant view on any subject at all is a very dangerous course of action.

I would like to suggest as an alternative – probably an unpopular one – that, if these things actually work commercially, and they continue to work commercially, then they will continue. And what I mean by that is, for instance, we know that our Gro Intelligence product is not viable at the smallholder level, but we are priced low enough that it is viable at just above the smallholder level. Then that individual is free to disseminate the information to everyone he or she deals with. That is a 'sustainable' model – to use a term that's popular for describing government-related and charity-related things – unlike a model that relies on political parties sticking with something that they said they were going to do. Policies change. For a model that relies on people's interest (as in the example of the data collection at the household level – and I'm not familiar with

LSMS but I certainly agree that it's very important), would it hurt to ask people to exchange their data for something of value? I don't know what that would be, but why not think of it that way, instead of just asking for it – even though they frequently will give it to you. And by the way, when you're asking for data and you pay for it, you get a certain type of data, as Ken pointed out; but when you ask and you don't pay for it you also get a certain type of data. There are people who won't give data away for free, and so you don't get their data. This is something that I think people should think about a little more than they seem to be doing.

Q: Richard Dickmann, *Bayer Crop Science Australia*

A question for Dr Street. We heard last night and this morning of the importance of diversity in diets. A lot of that around the world is provided by secondary crops. To what extent does the FIGS system provide a database that can help with the breeding of these secondary crops?

A: Ken Street

FIGS isn't really a set of databases; it's more an approach. So if we have the data associated with those secondary and relict crops, orphan crops, we can certainly apply to fix it, and that applies to wheats or people, and it certainly applies to weird and wonderful crops. So the idea would be, with these small collections, to try and assemble as much accession-level data as possible, particularly the latitudes and longitudes, and then we can apply a FIGS system to the breeding process.

Chair

Thank you to all speakers in this session.

SESSION 3: ICT ADDING VALUE FOR SMALLHOLDERS

Overview: **Unlocking the power of digital agriculture**

Dr David Bergvinson

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Abstract

Digital agriculture encompasses a value chain framework that supports smallholder farmers' access to services, knowledge and markets. This helps to unlock the economic potential of agriculture, preserve natural resources and accelerate equitable economic growth in rural communities. Digital agriculture is already the nerve centre for modern food systems. It enables democratisation of information and distillation of big data analytics to provide timely and targeted insight for farmers, input suppliers, aggregators, processors and consumers. These insights are now delivered to the location of a decision (e.g. a farmer's field on a smart phone) on how to optimise profitability, increase value chain efficiency and support consumer awareness on food and its impact on their nutrition, the rural economy and the environmental footprint of agriculture. Digital tools have the potential to compress value chains and reduce transaction costs, thus moving more value to the farmers' end for improving incomes and livelihoods. Through 'big data' and systems biology, the nutritional quality of crops can be improved by gaining a deeper understanding of the interaction of food, nutrition and human health. Spatial Data Infrastructure combined with unique digital identification can support an ecosystem of integrated services to better serve the needs of farmers – whether it be access to inputs, credit, insurance or markets. Downscaled observed weather data are critically important to support all actors along the value chain, given that agriculture is a solar- and water-driven industry. Maintaining the trust of farmers and consumers is vitally important, so policies to manage personal identification information are essential. However, data also needs to be granular to support precision agriculture practices. An ecosystem of different tools and platforms supported by pragmatic and visionary policies and institutions will position countries to uniquely unlock the power of digital technology to accelerate agricultural development and ultimately enable us to deliver on the Sustainable Development Goals – one country at a time.

What a privilege it is to be here and especially speaking on this topic of how to leverage 'information & communications technology', ICT, to support smallholder farmers. In essence, what we are talking about is how to make agriculture economically renumerative for smallholder farmers, and help them manage both market and production risks; to help them not only to realise

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

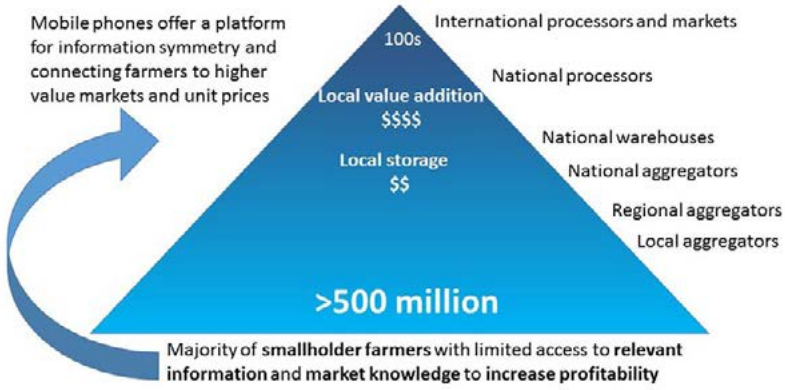


Figure 1. The pyramid of economic opportunity.

their full economic potential (Figure 1) but also to serve society through better nutrition – which is emerging as a theme from this conference. For the world's 500 million smallholder farmers, the challenge is information asymmetry, and our conversation here today is about how to leverage 'big data' and technology to address that constraint.

In fact, mobile phones have the power to bridge inefficient value chains that smallholder farmers are exposed to. How can we apply ICT to create opportunities for value-adding, for better market integration for smallholder farmers and, ultimately, to reduce the post-harvest losses that some farm sectors are experiencing? ICT can help improve the efficiency of value chains and create consumer awareness around post-harvest losses.

Digital agriculture can harvest this 'ecosystem' of new technologies that we have available, which includes:

- spatial data infrastructure;
- cloud computing;
- mobile phones;
- the 'internet of things' and sensor technology, which are evolving very rapidly, with graphene making that technology very compact and affordable;
- unmanned aerial vehicles (UAVs) or drones that are changing how we collect data (and I saw at CSIRO yesterday some of the fantastic advances that Australia has been making in this domain);
- image processing, as mentioned in all the previous talks this morning;
- advanced analytics and machine learning, as well as the analytical power we require and, importantly, the insights that we can gain through integrating maps or geospatial tools;
- unique identifiers – a very important issue – especially as they relate to the farmers that we are serving; these affect both our ability to deliver timely, tailored and targeted information and services, and also our responsibility around data governance and making sure that we do not betray the trust

of farmers in using that data; it is a challenge for the whole community to accept, to agree on guiding principles that make sure we use that data responsibly to serve society; and

- massive online open courses (MOOCs), with which potentially we could bring cutting-edge knowledge to millions of farmers, and create awareness around products and services to enable them to realise their full economic potential.

ICT will be the major conduit for delivering timely, targeted and tailored products, services and knowledge to increase rural incomes, improve nutrition, reduce risk and support sustainable agri-food systems.

ICT also has a role in the reconnaissance we need so as to understand the priorities of farmers, their needs, aspirations and how our science can serve them in order to develop sustainable agri-food systems for all of us.

Our challenge is to adapt these technologies for the developing world.

Competition

Another point I would like to highlight is that agriculture, or food production, is in competition with other sectors. Farmers need to think through this to create economic opportunity and also sustainability.

Consider Figure 2, linking the Sustainable Development Goals 2 (Zero hunger), 6 (Clean water and sanitation) and 7 (Affordable and clean energy). As we know, 70% of fresh water is used for food production across the world. In some countries it is far more than that, such as in India. Agriculture is going to be in competition with industry and urbanisation for those water resources. Think about energy: how is water used to produce energy, especially when we get into the bio-economy and second generation biofuels. All these variables need to be considered, and from the perspective of farmers who must look through the lens of economic opportunity and risk management, if the world is to achieve SDG 1, 'No poverty'.

Figure 2. ICT to help manage the nexus of water–energy–food.

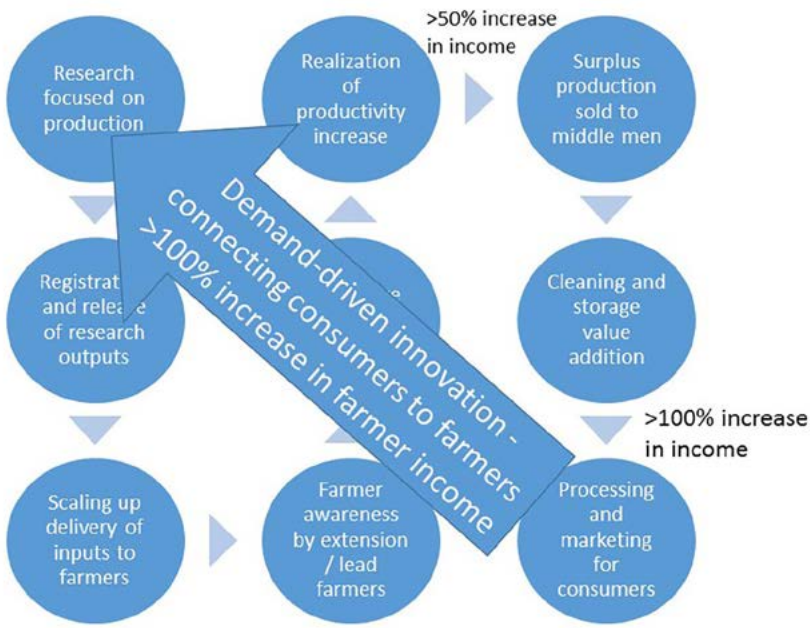


Figure 3. Compressing long and slow impact pathways.

How ICT can help farmers

Currently we have very long and slow impact pathways as we translate science into impacts (Figure 3). That chain can be anywhere from 15 years to 40 years in some developing countries. This chain in agricultural research has largely focused on increasing productivity, but increasingly we realise that it goes beyond that – as we heard in the Sir John Crawford Memorial Address last evening. We have to think about nutritional security, and that means thinking about processing and marketing, and creating awareness amongst consumers about better nutrition. It is there that a lot of the value has not been captured by smallholder farmers: in that processing-to-consumer segment of the value chain.

Demand-driven innovation can be enabled by ICT to help farmers understand where the market is going and how they can position themselves to capture the opportunities. There are opportunities not just in the production of food but also in early-stage processing that allows farmers to increase their unit price and allows that food to be more accessible and convenient for their own consumption, especially when it comes to nutritious crops.

To make all this happen, though, we have to connect the 'dots' (Figure 4).

Today's first presentation was on GODAN, the Global Open Data for Agriculture and Nutrition. That Spatial Data Infrastructure sits at the centre of Figure 4. How do we unlock the power of data to serve society? Agricultural innovation is going to draw heavily on this infrastructure especially as we go beyond the public–private partnership model (Figure 4) to include producers and the whole value chain.

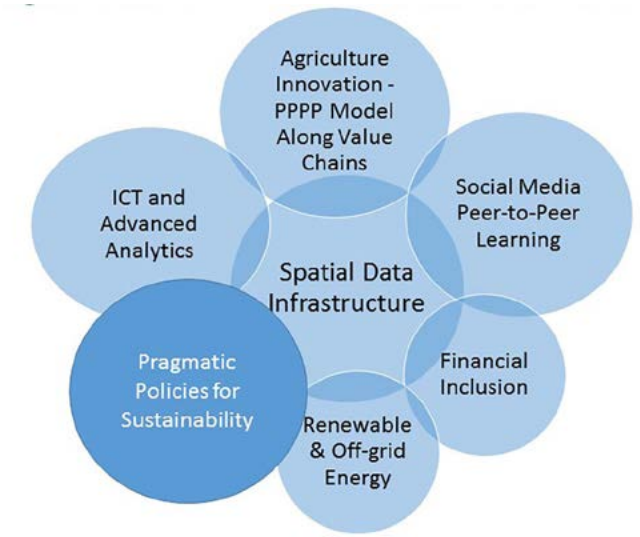


Figure 4. Intersecting domains for inclusive development.

Social media (Figure 4) is going to be critically important as we create awareness, among consumers, policy makers and other value chain actors, about the environmental impact of agriculture as a key driver to addressing climate change. Agriculture must not only adapt to climate change but also help mitigate it, through carbon capture and other interventions.

Financial inclusion (Figure 4) is not just about agriculture but also about how we stitch together research and financial instruments, and link the medical field with nutrition.

I mentioned solar energy already, for its use in pumping water and because farmers are selling energy back into the grid. For example, in India, electricity from solar panels is being fed back into the grid, and farmers are also making strategic choices around water use based on an economic model. ICT enables all this.

Also in Figure 4, high-end advanced analytics, cloud-based, allow us to consume all this 'big data' and deliver very simple accessible solutions to smallholder farmers ... but of course that requires pragmatic policies.

What policies need to be put in place to make this a reality? When we talk about 'big data', how do we ensure we protect personal identification so as not to betray the trust of the consumer? How do we put in place the incentives to drive sustainable agriculture, so that humanity lives within the ecological boundaries of the planet, one farmer at a time? All these considerations need to be thought about in designing ICT solutions.

Fostering youth involvement and effective communication

ICT is a powerful vehicle to bring youth back into agriculture. At ICRISAT we have converted our library into an agribusiness incubator to integrate agriculture

Figure 5. ihub – an ICRISAT initiative linking youth and agri-business.

with science, with financial services and off-grid energy, to create sustainable business solutions for smallholder farmers (Figure 5). We are finding that is attracting a young energetic population of scientists and entrepreneurs to come together to deliver these solutions and to serve those that have been underserved in the past with traditional models, including extension, market integration and value addition.

I want to end this overview by commenting on how we are communicating science. We have to do a much better job. Although overall the science community can be a little introverted, that should not stop us from reaching out to society to communicate our science at all levels, for example via:

- infographics that can influence and inform policy makers so that they make science-based decisions;
- interacting with our colleagues within the science community;
- interacting with farmers through peer-to-peer learning. Increasingly, in the United States and in Australia, farmers are learning from other farmers as trusted sources of information for practical solutions to real problems.
- engaging with the general community. We need to be at the forefront of communicating the value of the new technologies to serve society or we may find ourselves in a debate (like that over genetic modification) about whether the technologies are good or bad. Let us educate society on how we are using science responsibly to serve society and address the Sustainable Development Goals.

By communicating science we can:

- foster collaboration and innovation;
- enhance knowledge and career prospects;
- convey the importance of agriculture in eliminating poverty and malnutrition;
- make data-driven decisions for a better world.

We all need to make data-driven decisions, whether we are smallholder farmers deciding on the optimal mix of crops to deliver diversified nutrition and manage market and production risks, or whether we are policy makers deciding on budget allocations and on policies that can create either an enabling or a sometimes disabling environment for innovation to serve society.

In conclusion, I think the urgency of the agenda is critical, that agriculture touches on all 17 of the Sustainable Development Goals in some shape or form, and that we really need to come together as a community to build partnerships to accelerate the delivery of our science to serve society.

David Bergvinson joined ICRISAT in January 2015 to lead its strategy development to ensure science, demand-driven innovation and strategic partnerships come together to translate science into prosperity for rural families in the dryland tropics of Asia and sub-Saharan Africa. Prior to joining ICRISAT, David worked on the Agriculture Development team at the Bill & Melinda Gates Foundation and led their Digital Agriculture initiative. As Director General of ICRISAT, David continues to build partnerships that leverage the power of digital technology to accelerate the development and delivery of farmer-preferred products and services. To this end, ICRISAT is working closely with national partners along value chains of ICRISAT's mandate crops (sorghum, pearl and finger millet, chickpea, pigeonpea and groundnut) to ensure our science improves the lives of farmers and nutrition for all consumers. ICRISAT refers to these crops as 'Smart Food – Good for consumers nutritionally, Good for the planet by diversifying farms and Good for smallholder farmers by increasing their resilience and offering diverse market opportunities'. David is a Canadian national who has worked in international agriculture research for development for over 25 years.

Case study: Do MAD researchers add value for smallholders?

Stuart Higgins

AgImpact Pty Ltd

Abstract

This presentation explores the deployment of mobile acquired data (MAD) via tablet-based apps in research for development initiatives. It assesses pros, cons and unexpected consequences in the field, for both researchers and smallholder farmers, using the ACIAR-funded, University of Queensland Vanuatu Beef Project as a case study. In 2015, ACIAR sought to understand the potential benefits – intended and unintended – that mobile acquired data (apps on tablets) might deliver to its funded projects. In pursuit of this, AgImpact (an R4D company) was commissioned to design and manage a small research activity which reviewed nearly 20 'off the shelf' apps, then conducted three weeks of field testing in Indonesia surveying beef producers, in partnership with the University of Udayana. The researchers concluded that the use of apps for in-field research has significant potential to improve relationships between researchers and smallholder farmers by improving two-way information exchange in near real time. Some of the key findings were: (i) survey times were reduced by approximately 53%; (ii) 93% of farmers found the use of apps informative when research results were provided to them in near real time; (iii) 73% of farmers found the overall survey experience using apps to be positive. By mid-2016, the research activity had gained momentum and evolved into the ACIAR Mobile Acquired Data (MAD) research series, now involving nine ACIAR projects adopting apps in research for the first time. An exemplar project led by the University of Queensland, 'Increasing the productivity and market options of smallholder beef cattle farmers in Vanuatu', designed and built apps featuring auto-calculation functions, look-up tables and case histories, to track changes in cattle production performance and cattle prices for individual animals in real time.

AgImpact is a research-for-development (R4D) company based in Sydney. This talk uses a very brief outline of a specific case study to try and answer the title question: do MAD researchers add value for smallholders?

First, a bit of history. For 16 years I was a farmer on the Darling Downs in Queensland; 10 years ago I sold the farm so I could focus on international research for development; five years ago I started managing small research activities for ACIAR, mainly in Indonesia. The reason for telling you that is so you understand that I see R4D activities through the eyes of a farmer, and I have extremely low tolerance for machinery and technology unless it adds value.

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

Two years ago, Peter Horne, General Manager of Country Programs for ACIAR, commissioned AgImpact to evaluate off-the-shelf Mobile Acquired Data, otherwise known as MAD platforms. ACIAR was seeing a lot of projects allocating resources to building tailor-made apps from scratch, writing original code. Peter felt there had to be commercially available technologies that researchers could use to build research apps using very friendly drag-and-drop technology: you didn't need to be a computer programmer.

We performed a desktop study evaluating 17 off-the-shelf apps in the marketplace, and through a series of analyses and criteria we narrowed the list to two apps that we believed were most suited to ACIAR's types of projects. They needed to function in low-resource settings with quite complex workflows.

Pilot trials

AgImpact ran pilot trials with the two apps in the field in Indonesia with young university researchers, collecting data from cattle producers in the north of Bali (e.g. Figure 1). Kopernik, a local NGO, oversaw the independent evaluation of the users' perceptions of the apps. The mandate from ACIAR was quite clear and direct: to try and break the apps.

What I liked most about this study was that it aimed to understand the impact that the use of apps would have on relationships particularly between the farmer and the field researcher.

The pilot trials were to last for three weeks, and in the first hour we found a critical flaw that differentiated the two apps: it was to do with syncing data to the cloud. That meant we had three weeks then to focus on understanding these relationships, so we focused on knowledge and time: we asked what was the app doing to share knowledge between the researcher and the farmer, and what was it doing to the time spent by both on collecting the data?

Working with David McGill from the University of Melbourne, we built some apps using simple algorithms to calculate liveweight of the cattle. We would sit

Figure 1. Collecting cattle data in the pilot trial, Bali. *Photo: AgImpact Pty Ltd.*

Figure 2. Interviewing using the app rather than paper. *Photo: AgImpact Pty Ltd*

with farmers and ask them their cattle weights and then we would show them what the algorithm could do for them. This was real proof-of-concept.

The feedback from the farmers (this was quite a small subsample) was that more than 70% (up to 73%) were positive about receiving information back in real time; it was a huge benefit to the farmer. (I know David has since done more work in Pakistan on the experience of farmers receiving information using apps.) One issue they raised was that they were cautious about where the data would end up and who would be using it.

Then we looked at interview times. We simulated a household income survey and compared the time it took to interview using paper and also using apps (e.g. Figure 2). Very simply, using the app completed the survey in about 53% of the time it would take using paper. That was a result of using skip logic, calculations in the app and planning the workflow using the tablet.

Researchers might look at that result and think, "Wow, I can ask a lot more questions in the same amount of time", but from the farmers' perspective the shorter time is valuable because they can then get back to doing what they would prefer to be doing at that moment. That is value!

Conclusions from the pilot study. At the end of the pilot, we had to address three simple questions: (i) Should ACIAR promote going digital to the projects that it funds? We came to the conclusion that the answer was 'yes'. (ii) If so, which app? Our answer here, after a whole series of analyses, was an app called 'CommCare'. (iii) If so, how should ACIAR promote the use of apps? This was the question that triggered the MAD research series.

The MAD research series: an example

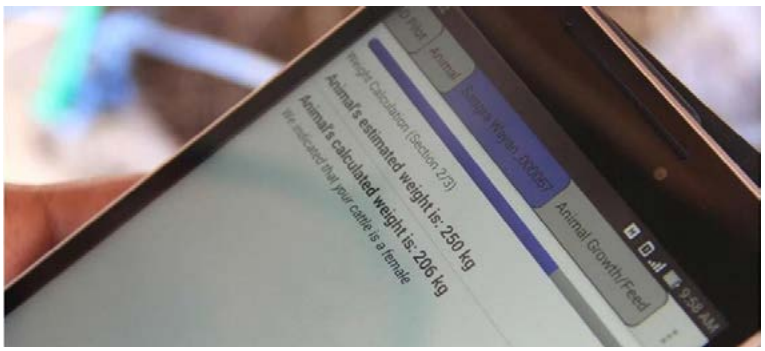
A year ago, nine ACIAR projects (Figure 3) started to adopt mobile acquired data, so those teams became MAD researchers for the first time. One example is the research project led by the University of Queensland (UQ), called 'Increasing the productivity and market options of smallholder beef cattle farmers in Vanuatu'. Dr Simon Quigley of UQ is the project leader, with Cherise Addinsall of Southern

Figure 3. Research institutions working with ACIAR in the MAD research series.

Cross University and Dr Scott Waldron (also UQ), working in Vanuatu. Although the project started only recently, they are already doing some really interesting things with MAD research and the smallholder farmers. Here is part of the transcript from a short video clip about the project (with both local and project-team speakers).

> *In the Vanuatu Beef Project we've been working with smallholder cattle farmers, here and in Espiritu Santo in Vanuatu, and we've been collecting baseline data on individual animals within their herds* [e.g. Figure 4]
> *...*
> *For me, the key thing that we've got set up is that we generate a summary form of liveweight of every animal we register on the day or measure on the day, and we can print that out in the field and give that to the farmer on the day that we do it. Next time, coming back, we can weigh them again*

Figure 4. Collecting data on individual cattle, and using the app to calculate and record liveweights. *Photos: AgImpact Pty Ltd*



and put it in here and you can see the change in body weight. And we also give some information, to give you some extension material.

...

My advice to someone starting out to build apps in other projects, is just to get in there and have a go. Don't be scared about crashing it. We've killed our app many times. Think through it logically. There's a new language to learn, but there's plenty of help out there. If you're having a problem, for sure someone else had that problem before.

...

At the moment, the use of the app is costing us time. A lot of time is going into the development and the deployment and testing and training using the app. Longer term, I've got no doubt that it's going to add value into our project, in that we're going to have more streamlined, efficient data management and analysis and those types of things. By the end of the project I expect it will be of great benefit

...

Conclusion

To finish, I want to point out that although the farmer may not have a tablet or mobile phone just yet, a researcher using mobile acquired data can actually pay that farmer for the data, not in currency but in 'knowledge', the universal currency. They can pay that farmer in knowledge. The critical component is real time ... because a farmer's brain is always working, it never stops.

Stuart has 16 years' experience in leading, managing or contributing to international research for development, primarily for multilateral agencies such as the UN Food & Agriculture Organization (Rice Policy in Laos), World Bank (Value Chain Studies in Africa) and Asia Development Bank (Irrigation Evaluations in Cambodia). Over the past five years, he has led multiple research activities on behalf of DFAT and ACIAR, predominantly in Eastern Indonesia, including the Mobile Acquired Data (MAD) Research Series. The MAD series aimed to evaluate the tangible 'value-add' of digital data collection apps deployed within ACIAR-commissioned projects and programs, and to understand the impacts of technology on the relationship between smallholder farmers and researchers. Prior to moving into the international research for development sector, Stuart was a primary producer (cotton & grain) on the Darling Downs in Queensland. He holds a Masters Degree in Agricultural Science from University of New England, is a recipient of the Vincent Fairfax Ethics in Leadership Award, and delivered an award-winning radio series ('Grow Your Own') on ABC Radio National.

Case study: The role of mobile technologies in promoting sustainable delivery of livestock insurance in the East African Drylands: Towards sustainable Index-Based Livestock Insurance (IBLI) for pastoralists

Dr Andrew Mude

International Livestock Research Institute

Abstract

The International Livestock Research Institute (ILRI) together with its partners launched a pilot index-based livestock insurance (IBLI) product in January 2010 in the Marsabit District of northern Kenya. It has since been scaled across the drylands of Kenya, and is also gaining momentum in Ethiopia where a pilot insurance project was launched in 2012. One problem inspired ILRI's IBLI agenda: finding a sustainable way to help pastoralists to recover quickly from the considerable losses they incur during severe droughts. Over the years, evidence of IBLI impact and value for money, and continued research and development on product design, as well as innovations along the service delivery chain, have helped with uptake, in convincing governments and development partners of its importance as a risk management tool, and have won IBLI a plethora of international awards.Briefly describing the key elements of the IBLI agenda, this presentation focuses on how the IBLI team leveraged a suite of digital technologies – largely mobile based – to help surmount some of the main obstacles to the provision of IBLI. Even in the sparsely populated drylands of northern Kenya, which the IBLI product targets, socioeconomic evolution has resulted in a growing density of mobile network coverage and a proliferation of mobile phone ownership, and use. Exploiting this trend, the IBLI team and partners have developed mobile applications for offline sales transactions and drastically reduced the cost and time to delivery of indemnity payments, as well as a whole host of other applications in information exchange and knowledge dissemination.

I am leading a program on index-based livestock insurance. This is a product that we developed having identified that risk of drought-related mortality of livestock was the greatest source of vulnerability faced by extensive-livestock keepers, pastoralists. This product was a solution. As we went about designing, developing and implementing this program we came across a lot of challenges, for which we found a number of solutions through the use and exploitation of mobile technologies.

First, some background about the context and why we use insurance. The area that we are targeting is the arid and semi-arid lands of Kenya, Ethiopia and East Africa, which account for over 60% of the land in this region. These areas

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

are pastoral regions, and extensive-livestock keeping is the key production system. There is plenty of evidence, over decades – collected and written up by myself, my colleagues and others – showing that risk in these areas not only makes people poor by reducing their incomes and destroying their assets, it also keeps people poor by discouraging investment and distorting patterns of asset accumulation. And in an environment such as this where livestock is the key productive asset, the key source of income, we hypothesised that there would be great development impact in providing these pastoralists with a risk-reduction risk-management technology, such as insurance.

The question was, how do we develop an insurance contract that is suitable to this kind of agro-ecology, to this risk profile, and to the basic infrastructure-deficient and remote environment these pastoralists live in?

We stumbled upon new technology in insurance: index-based livestock insurance (IBLI), which uses satellite data to estimate the amount of forage available within a season and related livestock losses. We were able to develop a formula upon which insurance could be written. So then the objective of our research and development program was to test our hypothesis, namely that insurance could make a significant and sustainable contribution to reducing the challenge pastoralist populations face in managing risks of drought-related livestock mortality.

The first product was launched as a pilot in northern Kenya, at Marsabit, in 2010. In 2012 it was rolled out in southern Ethiopia, and since then the program has grown quite a bit with governments being involved. The sustainable index-based insurance program has five components:

- precise contract design – over the years we have brought in new technology using the intersection of remote sensing and spatial econometrics, to make sure we design value-adding contracts that actually manage the risk being targeted.
- evidence of value and impact – in both northern Kenya and southern Ethiopia we have been following a range of households across the years to ascertain household-level social and economic welfare benefits of insurance, as well as value for money. The positive evidence generated therein has helped uptake and support by governments and development partners across the years.
- establish informed effective demand – it was critical to make sure that we catalyse and stimulate demand from the pastoralists, and that they understand what they are purchasing, because they have very low literacy and insurance is utterly new for them. This was quite a difficult challenge.
- low cost, efficient delivery mechanisms – we worked with our insurance and other delivery partners to reduce the cost of delivering insurance and delivering the services that are necessary along with insurance, and it is in these two areas that mobile phone technology has helped us quite a bit.
- policy and institutional infrastructure – we're currently working very closely with the Kenyan Government, the Ethiopian Government and other partners as they take up the product and integrate it within their own government

systems. The Government of Kenya has the Kenya Livestock Insurance Program partnering with this project. They have taken up the contract that we have designed and are working in a private–public framework to help scale it sustainably. We provide them with technical support.

Delivery challenges

The lands where we are working are quite remote and deficient in infrastructure, which leads to challenges in delivery of insurance. This problem could be solved by application of mobile and digital technologies. Figure 1 shows our data from annual surveys on mobile phone use in Marsabit. Round 1 was in 2010 and round 6 was in 2015. Essentially we asked householders: "How often do you use a mobile phone: never? once a year? ... every day?", and you can see the line for 'every day' increasing steadily to 2014 and then drastically in 2015.

We have been able to leverage mobile technology in three different ways in support of IBLI:

- mobile phones as a service delivery tool – delivering sales; delivering premiums; delivering information;
- mobile phones as a training and performance assessment tool – mlearning and gamification; tracking impact of training on sales;
- mobile phones as data provisioning tools – crowd-sourcing for rangeland conditions; livestock market information systems;

and we think the technology could be valuable for other types of interventions in this area also.

Service delivery. One of the big challenges we faced from the outset was that the insurance companies we partnered with were using point-of-sale devices. In 2010 each of these cost about US$12,500, and that limited the number of

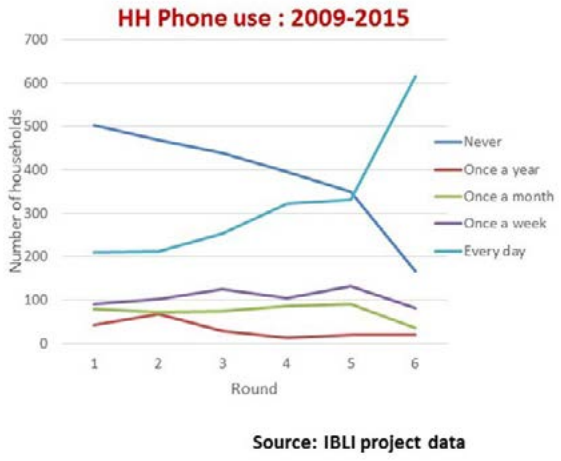


Figure 1. Leveraging mobile technologies for IBLI and beyond.

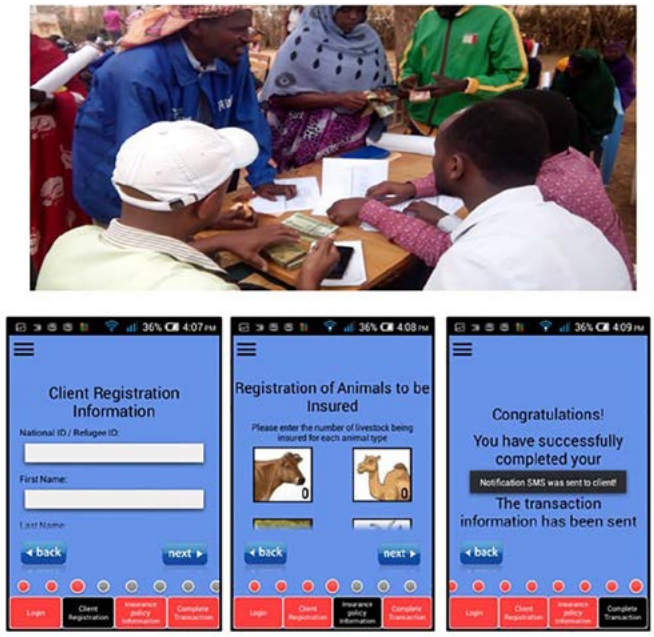


Figure 2. Contrasting the manual and mobile methods for engaging new IBLI clients.

agents that could be employed to provide products for sale to clients. The lack of sales agents was really affecting sales and accessibility. So we worked with insurance companies to develop sales transactions applications (Figure 2). At the time, 2011, this was quite novel. These applications really helped increase the number of active sales agents and therefore the awareness and availability of the insurance, and they allowed for better data management and a range of useful analytics on agent behaviour.

They also helped with the delivery of indemnities, because the pastoralist population then had few phones; indemnities were being delivered manually, via Toyota LandCruisers ... if the agents could identify where the pastoralists were. As you can imagine, the cost of trying to deliver indemnities was a lot more than the value of the indemnities. We were at the pilot stage of the program and wanting eventually to promote and catalyse a sustainable market, so we really needed to solve that issue! Now, with mobile technology, indemnity payments are increasingly paid through M-PESA, a popular and innovative mobile money transfer service in Kenya, or online bank accounts.

Another challenge we faced with service delivery was how to build awareness and trust in the product. Clients often asked, "If this is working really well now, what was the situation in 2009 or 2011?", which are years that they identify with drought. So we developed an application that sales agents could use to show the index of data on a hypothetical contract in the past, to answer that question (Figure 3). It has proved quite an important tool for the agents.

Figure 3. The index calculator showing IBLI performance and what would have been the payout on a hypothetical contract in a previous drought year.

***Training and performance assessment*.** Currently the two insurance companies offering the product have over 500 insurance agents, and one of their largest costs is in training, extension and performance assessment to make sure the agents understand the product enough to catalyse and generate demand. As well as being very expensive, literature has shown that this type of training is not very effective. So we began developing learning tools to provide the standard IBLI training curricula. Again, we started rolling these out via a pilot trial with a particular type of insurance company using a randomised controlled-treatment type of design. We found that agents who trained with the mobile application (which offered incentives either as cash or via gamification – leader boards) brought in three times the volume of sales. That result led the insurance companies to ask us to work jointly with them to continue developing their mobile learning profiles for IBLI.

Data provisioning

As satellite data in regional conditions does not show how palatable and nutritious the forage is, we have run a crowd-sourcing pilot project with

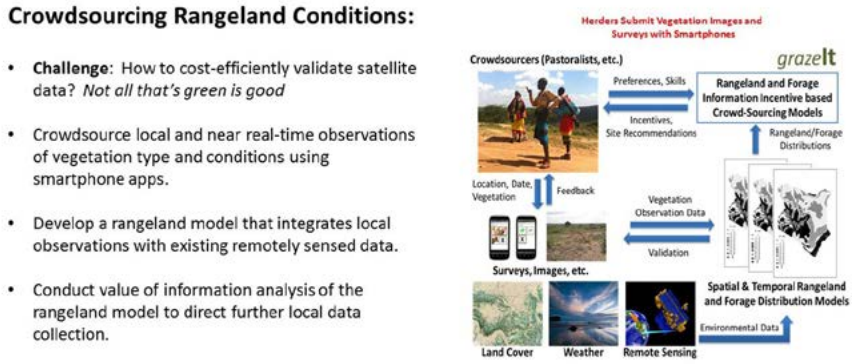


Figure 4. The data provisioning project with pastoralists providing data on forage quality.

pastoralists (Figure 4). In this project, about 100 pastoralists over four months sent up over 120,000 photos of forage, which were processed by our partners at Cornell University's Institute for Computational Sustainability. The success of this showed us that illiterate pastoralists were able to collect various types of data.

Now we have begun a new program using crowd-sourcing logic to try to improve on livestock market information systems here. Over the years much money and many resources have failed to come up with a sustainable system of data that is of high resolution and quality, and we think our method may be able to solve this. Again, we have begun a pilot trial and it is ongoing at the moment.

In outline, a client organisation requests reports on specific types of data on, say, cattle. Our system administrator designs surveys, reports and dynamic incentive structures that can facilitate collection of the required data. The survey is sent out to the crowd-sourcing population. On contributing information, members of the population receive an incentive payment via a mobile platform. The data is validated and delivered to the client in usable formats.

Conclusion

This talk has given a snapshot of the emerging influence of mobile applications in challenging physical terrain. As you see, mobile phones are an asset that can allow access to far away markets and opportunities, unlock underutilised resources, and make innovative applications available to otherwise isolated users.

As we collect this data, we are referencing 'big data' and analytics for generating evidence-based and data-informed policies and also behaviour change for all the various actors, from policy makers to farmers.

Critical regulatory questions remain, such as:

- issues of data ownership and security;
- privacy; and
- the enabling environment and digital literacy.

Acknowledgements

Figure 5 acknowledges the large range of partners that we work with.

Figure 5. Acknowledging the partners in the IBLI program.

Andrew Mude is a Principal Economist at the International Livestock Research Institute based in Nairobi, Kenya. His portfolio deals largely with developing innovative evidence-based technological solutions to ensure the productive and sustainable use of livestock by dryland populations. Andrew leads the multiple-award winning effort to design, evaluate and scale livestock insurance to help millions of poor herders and their families who care for and depend upon their livestock under conditions of considerable drought risk. Widely published in peer-reviewed journals, and featured in numerous prestigious media outlets, Andrew was the 2016 recipient of the Norman Borlaug Award for Field Research and Application, which recognises exceptional science-based achievement in international agriculture and food production by an individual under 40 years of age. Andrew completed his doctoral degree in economics at Cornell University in 2006 and was a mid-career fellow of the Sustainability Science Program at Harvard's John F Kennedy School of Government in 2011.

Q&A: ICT adding value for smallholders

Chair: Dr Joanne Daly PSM

Crawford Fund ACT Committee member & CSIRO Honorary Fellow

Q: Joanne Daly, Chair

What do you see is the greatest impediment to the uptake of digital technologies by smallholder farmers? Is it the applications? Is it access to devices or networks? Or is it something else? Perhaps David would like to start?

A: David Bergvinson

I think it's country by country. The context of that question varies. Access in many parts of sub-Saharan Africa still is an issue, especially the cost of data. We talk about 'big data' and distilling it, but at the end of the day it's still data, especially when it comes to imagery. The cost of data through mobile providers is a constraint for farmers.

A: Stuart Higgins

I'd concur with that. For the work we were doing in Papua New Guinea, with five projects, the data is really limiting them. Tablets are an upfront cost, but the data is very expensive there. That's on the farmers' side. On the researchers' side, they also have that problem around the cost of data, but what's holding back researchers in countries where we're partnering with research is the training and the knowledge of how to build these simple apps. That's probably what's needed next.

A: Andrew Mude

I would say it's time. But I'd also agree, in this context, the cost of data, and also access to mobile phones themselves. I mean, we've seen a big increase, but the phones are basic, and smartphones can use more applications. That can serve both farmers and their representatives or policy makers, and it will take time before there's a critical mass of people – in the context that I'm working on, pastoralists – who have these. But in the end I'd say the limiting factor is the cost of data.

Q: Caspar Roxburgh, *The University of Queensland*

Great presentations. I suppose this question is really directed to David. I work on an ACIAR-funded project in Africa, and part of my role is to work with an ICT tool for communicating project results and findings to farmers. Something that I've learnt and discovered, talking to other people doing similar things with other projects, is that these tools require quite a bit of financial investment to build. They require quite a lot of time: ongoing time to help update them, debug them and keep them functional and relevant. And they also require multi-disciplinary teams, because you need IT developers, and you need researchers to help formulate content, and you also need communication specialists to understand how to package the story. I'm interested in what you see as the CG System's or

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

maybe just ICRISAT's view on how to manage this investment. Because if you're a researcher and your job is to, in part, work with these tools, you're working on something that is not a traditional research output, and it comes into conflict with your own requirements to publish and conduct scientific research.

A: David Bergvinson

I agree, thanks Caspar. Yeah, great question. That's actually why we started the ihub, recognising that researchers have a lot to offer on insights, but that delivery of the knowledge and sustainable solutions really requires entrepreneurs. So what's happened with ihub is, we've brought in that ecosystem of disciplines to not just design and develop but also deliver those solutions faster – and, I would even submit, at a lower cost. So I think that kind of innovative thinking needs to happen around the world where this intersection of research and entrepreneurship needs to be supported. I think if you do that you'll find that the return on investment is high.

A: Stuart Higgins

I'll add one comment to that. In the MAD research series that we are doing, which wraps up this month, as part of that research we are evaluating quantitatively the amount of time researchers are spending in transitioning from paper to apps. We've been monitoring that with them. We've been monitoring the amount of time AgImpact, our support team, is spending in supporting those projects, adopting apps. We've also been evaluating the amount of dollars that they have had to spend in adopting apps. Those findings will be out in the next month or so. We've spent the last year doing that with nine research projects, four of which are core projects. I think that was a very insightful question that ACIAR posed a year ago, for us to have some of that information now, so that people can really understand what they are getting involved in; whether this is going to cost them a lot of time, a lot of money; and so on.

Q: Joanne Daly, Chair

Andrew, do you have a comment on how to achieve the balance for researchers between research output and building and sustaining these applications?

A: Andrew Mude

I would echo what David has said, in the sense that, even as we have developed these applications, the importance of the partnerships we have formed with commercial players – those who would benefit from the applications, as well as those who make the applications – is quite important because there are synergies gained by the contributions that each can make. And also for researchers, as has been indicated, there are a lot of benefits that we get from the increased access to information, high resolution information, which can really increase the value of the research we do and the insights we can deliver. So I really think harnessing these partnerships is essential.

Q: Ros Gleadow, *Monash University*

My question is initially to Stuart, but the others may like to comment as well. With the increasing use of social media and posting of photos, there is so much data out there and available already on social media which you could

be harvesting and adding to your data sets, rather than having specific apps. Is there a move to try and use some of that via an app that can gather existing social media data?

A: Stuart Higgins

I have to confess I'm a social media dinosaur. Fortunately, the people I work with are more social media savvy. I know of one ACIAR project, which I think is in Vietnam, where they are using social media in collecting data as well as in communicating. I'm sorry I don't have much information on using social media to collect the data and how that would happen.

A: David Bergvinson

Yes, I think it's going to become increasingly important, not just in collecting the data but actually within communities of practice, to share the knowledge that comes from that data. Facebook is quite keen on this. Another company they acquired, Whatsapp, is being used in many parts of the developing world as closed loop social media for supporting rural development. So I think you're going to see social media used in different ways, both for public data but also private data.

A: Andrew Mude

I think it really depends on the type of data that you want to be collecting. Social media and all these forms of generating data will generate a whole bunch of data that sometimes might not be of value, so you really have to be thinking about what the application is. For example, in some work we've done with pastoralists, it's really important for us to understand their movement patterns, and understand if the provision of insurance or other interventions will affect their movements. About four years ago we had a costly project in which we collared a few cattle and those collars of data collection were quite expensive, but now we can use pastoralists' phones, their phone signals, to track their patterns of movement. Now the challenge is access to that data and ownership of the data, and that's something that will be increasingly important to think about, because you can't just make use of that data without subscribing and requesting or acknowledging its use.

Q: Roger Wickes, *The Crawford Fund South Australia Committee*

One of the big issues is privacy of the data. You are collecting more and more data. I've worked out that the supermarket chain knows what I buy, what I eat, where I go and how much I pay for most things, and how much I drink, and that's starting to be a concern. You're collecting data about cattle on individual properties. We had a protocol in soil science about lifting that to a level where you can use it. Are there any protocols for your uses? There doesn't seem to be much protocol around privacy.

A: Stuart Higgins

I can touch on that briefly. Last year we had a masterclass in Canberra and one of the sessions was on ethics, and the ethics of digital data collection. There's an information pack on that. So we have certainly covered that topic and explored it with the research projects that we've been supporting through ACIAR. The

technology that we've been using has been widely used in the healthcare area, so it has the highest level of security. Interestingly, we've found the least secure aspect of data collection is the person walking around with a tablet, without a security code or a lock or something like that. Yes, I am concerned when I look up something on the Internet and suddenly I see ads for it for the next week. It is a concern.

A: David Bergvinson

I think this is a good question, and as a community we really need to come together quickly on this, at least to form guiding principles and certification of organisations that comply with those principles. It is actually a very complicated issue. We can draw on the examples of the health sector, but then it can be like the precautionary principle in that you are so cautious that you cannot unlock the value of the data for the customer. Finding that balance is really important, and it depends on the type of data being collected.

A: Stuart Higgins

If I could add one more comment to that. What we have experienced over the last year and a half is that you may have a project that is looking to use digital data collection, and participants will be enthusiastic and their in-country partners will be very enthusiastic. But I would strongly urge project teams to be discussing the matter with the higher level in-country partners, asking their views around data security. Because that will very quickly slow down the adoption process unless you manage perceptions – and not only manage perceptions but also inform them. We encourage those questions. It means people are really thinking about what they're doing. Projects looking to use data should have those discussions sooner rather than later because the reactions can often be a last minute surprise.

A: Andrew Mude

As researchers, one of the things we typically have to follow is research-ethics compliance. I think for those of us now working with this new type of data collection it is important to think about what research ethics would look like, and not just research ethics but, because the accessibility of the data makes it so much more widespread in its use, also the ethics related to the generalised use of it, beyond just research.

Q: Ernest Bethe, *International Finance Corporation*

I have a question for all three speakers. At IFC, we invest in companies, private companies and then we work to link these private companies with smallholders. What we see, or what I see (maybe others see something different) is that in a lot of the countries in which we work, the public extension service and public research are declining relative to the amount of private extension or private touch points. Stuart, in the project that you did, and David in what ICRISAT is doing, and Andrew within IBLI, what is the involvement of the private sector? Are you looking at how these mobile acquired devices can be used by them, and then comparing that to the public side?

A: Stuart Higgins

In AgImpact, outside of our work with ACIAR, we also support the private sector in the adoption of digital data collection, and it is growing very very quickly. They are using it for pure research and they're also using it very much for their logistics and their supply chains. Although I would say they are behind the 'research curve', they are certainly really taking this on.

A: David Bergvinson

An area of greatest growth is the private sector's use of these tools to better serve customers. I think that, from the perspectives of donors to the CG System, there is an increasing recognition that the private sector is going to be key, with sustainable scaling of solutions for smallholder farmers within commodity catchments, and integrating services. We heard Mario Herrero [Session 2 this *Proceedings*] speak about mixed farming and how we grapple with the complexity of this. The private extension systems are increasingly taking up that role, largely because governments are not investing a lot in public extension services. I think it is a critical question to be asking policy makers: What are the incentives to further catalyse private sector extension, but in a responsible way so that information comes back?

A: Andrew Mude

Within my program, in order to deliver insurance, we recognised it needed to be market-mediated. So we have been working very closely with insurance companies and with other aggregators. In Ethiopia we are now working with a financial company – a digital financial infrastructure company – that is working to deliver not just insurance but also finance and other types of agriculture extension services. We see more and more of this happening. Also among my colleagues at the International Livestock Research Institute, and also I think in other parts of the CG System, there is greater encouragement to work with private companies, particularly since we are told more and more to think about impactful research, and to think about scale. So it is becoming more critical to recognise that you need commercial players to help drive the products and technologies of the science that you develop.

I would say that even the donors are encouraging this. More and more donors are coming online, and even traditional donors are starting to have an increasing pool of resources directed at developing and encouraging partnerships with private companies, or even requiring private companies to take the lead in partnerships with research agencies and NGOs and so on. So there is that movement going on.

In regard to extension, in the field that I've been working with, I see a lot of healthy collaboration between public and private. For example, I mentioned development of sustainable market systems. This was a government function but they have realised that they might not be the best suited to actually collecting and disseminating and distributing good data, and so we are working closely with companies who might be better placed, such as Safari Corp. So I do see this trend happening, and I think it can be positive for both public and private.

Q: Guy Coleman, *AgriEducate*

We have heard recently from Dr Akinwumi Adesina, who was the World Food Prize Laureate in 2017, about making agriculture a really cool choice again for youth, and also from Dr Lindiwe Sibanda last night about Africa being the youngest continent in the near future. I'd love to hear your thoughts, from David and also Stuart and Andrew, about how we best capture this youth engagement effectively and capitalise on perhaps an ever growing opportunity in the future?

A: David Bergvinson

Well that was one of the intents of ihub, to get youth involved in the design, development and delivery of these solutions. They know the constituency they are trying to reach out to, because they are in it themselves. That's one avenue. I think another is that we need to support entrepreneurship training in rural communities, so that we empower youth in rural communities to see agriculture as a viable business and to be thinking about ways in which they can respond to market opportunities. I don't think that's really instilled in many universities or high schools around the world, and it is very important. And a third way, I think, is by making sure that we have a policy framework that supports this as well and creates the awareness and provides the right incentives for youth to be looking at agriculture as a viable business. Different countries are approaching this differently, but I think it's an issue that has largely escaped the attention of policy makers. When you look at the average age demographic of farmers around the world, whether it be in Australia or Angola, you're going to be shocked. I think it is something we need to urgently address, and I believe that needs to start in the school systems.

A: Stuart Higgins

I talked about this for many years when I was a youthful farmer. My view is, we all want to make a difference, no matter what age we are. My understanding is that the youth of today want to make it bigger and quicker, and I get that, and that's great. For me, what appeals more, or the way to appeal more to youth these days, is by creating or promoting that link (we heard about it last night) between health, the environment and food security. It's not just agriculture. If you want to improve someone's health, get into agriculture. If you want to improve the environment, get into agriculture. That's been my catch cry for a few years: if you want to solve a lot of the world's issues, start working with a farmer.

A: Andrew Mude

I was interested in Stuart talking about moving from farming to international research. I don't know if I'm still counted as youth but I'm thinking of moving the other way. Probably my sample is not very wide, but I do feel that one of the key things is really to demonstrate to youth that farming is a viable alternative livelihood that can generate a substantial living for them. I think that message is getting around. In Kenya I see more and more popular information out there. For example, in the regular newspapers there's a segment called 'Seeds of Gold' once a week and it is one of the most popular segments. Youth, as you said,

are the ones accessing information through social media so I think that will be very important. I know governments in Kenya, both the national and the county governments, are providing access to finance for youth and youth groups for agriculture, and providing more support to them through agricultural innovation or accelerators in Ethiopia and in other places. So I think, with an increasing attention to delivering information on the value of agriculture to youth, probably you'll start seeing an upswing in youth looking into agriculture.

A: Stuart Higgins

Can I just add one comment ... What the Crawford Fund does by having its scholars and their mentors, that is what is needed. When I first started being a young farmer, the mentors that I had were incredible. The more mentoring that can go on, the better. If you sat me in a room with a young farmer for half an hour, I reckon I could nearly convince them that farming was the way to go.

Q: Zelalem Moti, *PhD student, University of New England*

My question is to Andrew, about local context, how it really affects the new digital applications for smallholder farmers. Andrew mentioned some of the challenges, such as access to smartphones and also digital literacy. I know for example in Ethiopia they are using a lot of languages with the smallholder farmers, but maybe it's not a problem in Kenya, where most of the farmers also speak English and handle smartphones. I want to know more about how this local context is affecting the use of these digital tools among the smallholder farmers.

A: Andrew Mude

This is a really important point and you are right, particularly in Ethiopia. I mean when we're talking about developing mobile content or even e-learning content for training insurance company executives and agents, training the local government extension workers, and so on, in Ethiopia we have found that we needed to adapt our content in terms of language. The English language curriculum was not effective. We had to develop a specific Ethiopian language product, and change not just the language but sometimes also the type of scenery, the type of illustration. The same is true in Somalia, where we are now working. In Kenya, it was a bit different: I think most of the literate people speak at least English or Swahili so we were able to limit ourselves to those languages.

I mentioned earlier about the work on the mobile learning and how the initial resource got the insurance companies really excited. We had one insurance company that had mandated all their agents to go through the end-learning course it required for certification, but half of their agents were not digitally literate, so that became a problem. That resulted in a change of agency and a change in the requirements of what incoming agents had to do and, in this case, that digital literacy would be required. So context is something that is important to think about, and who your client is. Sometimes the client is not just a farmer but the service provider to the farmer. You're right, these are issues we need to be attentive to as we develop content.

Q: Wendy Umberger, *Centre for Global Food & Resources, Adelaide*

My question is directed to all three speakers. I think you mentioned that uptake of smartphone technology has been incredible in this last decade, and that while researchers are using this technology to enable their research and enhance smallholder livelihoods, the people sitting in higher authorities in power might not be as enthusiastic and as excited to use this technology to collect data. How do you think we can effectively communicate the relevance and use of smartphone technology to those people high up there, and make use of it?

A: David Bergvinson

My short response is the real-time dashboards, that design pragmatic policies to serve society.

A: Stuart Higgins

I'd certainly support that, showing them the value. They are probably not aware of the value right at this moment.

A: Andrew Mude

I think, as Stuart and David both mentioned before, that it would be important to integrate some of these stakeholders, the high level stakeholders, from the start of your project. In our case, for example, both for livestock insurance and livestock market information systems, the government, after being convinced, has come on board and is pushing for the development of these types of services. So I think, even though the more senior members of society might not be as digitally savvy, I still think they are aware of the impact that smartphone technology might have. Given this is the objective, I think bringing them online and demonstrating to them the value, through tools and dashboards as was mentioned, should help convince them and draw their support.

Q: Joanne Daly, Chair

Thank you. I think also, delivery of results and community demand ... that is what people higher up the 'feeding chain' often respond to, isn't it.

A: Stuart Higgins

And if a young scholar has excellent data presentation skills, I think you will find that will be in more and more demand in the years to come. The better you can communicate this massive amount of data, the better you'll be looked after.

Chair

Thank you to all speakers in this session.

SESSION 4: TRANSFORMATIONAL CHANGE BASED ON INNOVATION PLATFORMS

Overview: Taking the hope and fear out of agricultural service innovation

Dr Mike Briers AO

Food Agility CRC and Internet of Things Alliance

Abstract

Agriculture lags other sectors in the development and uptake of digital services needed for safe and sustainable food production. Challenges to digital readiness include Internet connectivity in rural areas. Whilst connectivity solutions are emerging, two key enablers of digital service innovation are lacking and often overlooked. The first is the absence of reliable underpinning information systems calibrated for decision-making (knowledge infrastructure) to enable services to be scaled and repurposed for different use-cases. Progress is being made in the development of such systems which will attract new investment and open many transformational opportunities across the food and agriculture ecosystem. The second relates to the maturity of contemporary lean start-up approaches to iterative co-design and market validation prevalent in the sector. These methods place the customer or service consumer at the centre of a co-creation process to ensure that value is delivered and ultimately adoption is maximised. This is particularly relevant for agriculture in both advanced economies and developing countries characterised by a highly complex and volatile decision-making context. Designed and executed well, this approach to deliberate service innovation removes the hope and fear elements more commonly experienced.

I feel a little bit humbled by the number of people in this room that genuinely care about the world and want to do good things in that world. I spent 20 years of my professional life in commercial business in the fintech industry, almost at the dawn of the Internet age and the first really 'big data' types of applications. For the last five years, as a student of agriculture, I have tried to understand the lessons that I learnt over that time, as they can be applied in agriculture.

First, here (Figure 1) is an update to a table Steve Mathews showed [Session 2, this *Proceedings*]. This is an Australian version of the table (it does not include hunting!), and is more recent. In the Food Agility Cooperative Research Centre (CRC), we are trying to answer open questions about how to move agriculture up this table in Figure 1, out of the red into the green. An important difference between this table and the one Steve Mathews showed is that the lowest six rows of this table are labelled 'Asset intensive industries', and the four rows at

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

Figure 1. Australia Industry Digitisation Index, 2016 or latest data, based on a set of metrics to assess digitisation of assets (6 metrics), labour (5 metrics) and usage (26 metrics).
Sources: Australian Bureau of Statistics, Appstore/iTunes, ASX300 annual reports, Australian Dept of Immigration & Border Protection, Facebook, Google Play Store, LinkedIn, Twitter, McKinsey analysis.

the top are labelled 'Knowledge intensive industries' (which is where I'm from – finance and insurance). The first open question is: What does it take to move agriculture into the group labelled 'knowledge intensive industries'?

Barriers to adoption in digital agriculture

Stuart Higgins spoke earlier about MAD – mobile acquired data – and already today we have seen many great examples of mobile use. It is often claimed that connectivity in the rural areas is a barrier to digital adoption in agriculture. But there are new solutions (in Australia, mesh networking data systems and so on) that don't rely on the Internet as much. Here's an example from Uganda with bananas. In Uganda the average consumption of bananas is the highest in the world: people eat something like 0.7 kg of banana per head per day. A program called 'YouReport' enabled a network of around 200,000 Ugandans to report on the prevalence of a banana disease. This level of participation has enabled the YouReport people to map out the prevalence of that disease (Figure 2) in

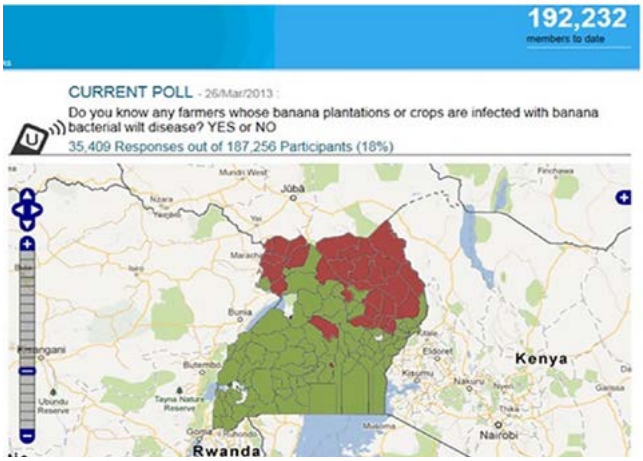


Figure 2. Detecting and mitigating disease in bananas, a staple food in Uganda, has been achieved by use of mobile phone technology.

order to be able to control it. More importantly, the example shows first that Uganda has 'jumped over' copper and moved straight into mobiles; and also that mobiles are allowing people to be educated about ways to minimise and mitigate that particular disease. This is an example of using MAD.

Nevertheless, there are two key barriers to adoption of digital technology, other than the Internet and connectivity. One of them is very technical, and one of them is very deeply human, and I think these are sometimes forgotten.

The technical barrier is the absence of reliable underpinning information systems that enable services to be 'scaled' and repurposed for different situations ('use-cases'). The human barrier is a current lack of mature approaches to iterative co-design and market validation which focus on delivering value to the consumer of technical services to maximise service adoption.

Technical barrier: bridging the digital divide

The framework in Figure 3 helps my team fill out the picture and the opportunity in digital agriculture. It arose out of a lot of industry consultation, which looked simply at two demand drivers and two supply drivers. On the left of the diagram you see 'Produce the right thing', which is essentially a digital feedback system: feedback tells people in the supply chain what to produce and how much to produce. Digital technology has a significant role to play in that. The right thing for the brand may be nutritional and other provenance or food safety characteristics of food products in the hands of consumers (top right-hand side of diagram) – authentication (whether provenance or safety) can be enabled by attaching a digital story to the produt as a feed forward system.

The bottom half of Figure 3 refers to two supply drivers that have been mentioned already today. One is access to finance (essentially, reduction of risk and uncertainty, and how data can be used as evidence of sustainable farming practice to reduce premiums on finance and capital and insurance and so on).

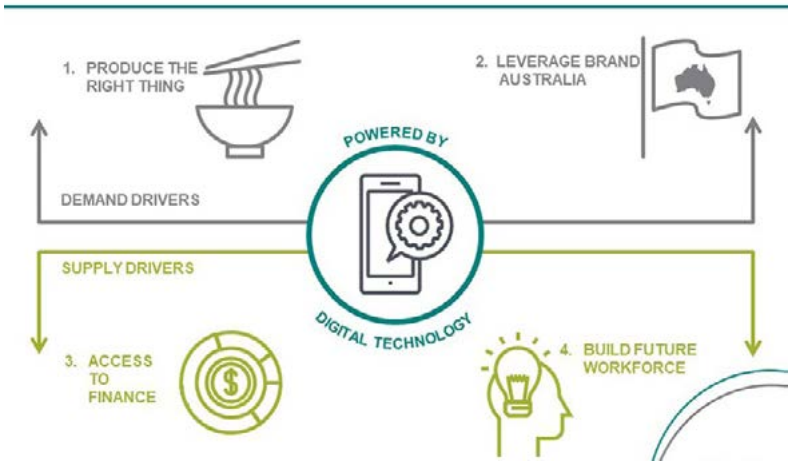


Figure 3. Four challenges for impact.

And the other supply driver is people – so the input side is dollars and people – and there are various types of digital services that can increase the digital adoption and digital education.

The first thing that I noticed, as an outsider to the system, is that the agri-food industries and digital technology have only recently come together to try and bridge the digital divide. That is why we now have a plethora of discussions, including this conference, linking digital technology and data to agriculture.

In my view, there have been good reasons for that delay. One reason is that we are on a journey to better educate technology providers about the reality of particular industries, and of those it seems that agriculture is the most complex and the most volatile.

Farmers seem, to me, to be the ultimate entrepreneurs. They make decisions based on very little forward information (maybe many of you in the audience take that situation for granted), whereas other sectors are much more predictable and much more controlled. For them, digital technology is a lot easier. Therefore part of our mission is to educate the technology providers, to give them a more nuanced and sophisticated view of the agricultural sector.

To 'scale' and develop services, agriculture can take lessons from highly mature sectors. We need apps that are reliable; we need stable and robust measurement systems; and at the moment we don't have those. We have very fragmented measurement systems and we have silos up and down the supply chain, and things called 'tombs' where some of the data that has been collected is just sitting unused, as someone mentioned earlier – no-one is doing anything with it, even though it is potentially useful.

And so my team has been promoting the notion of data in circulation (Figure 4), by building use-cases (example situations) and proofs-of-concept (evidence) that allow and demonstrate the value of data – if we can only break down the silo.

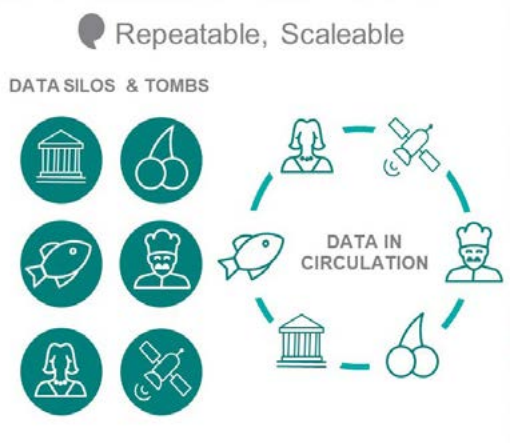


Figure 4. Stable and trustworthy measurement systems matter.

We ask: What does a service looks like that tells a grazier about the quality of the meat from the viewpoint of a meat processor or the viewpoint of an end-consumer? We want to be able to produce those types of proofs-of-concept.

Importantly, this also underpins scale. In terms of technology, 'scale' means how you extend and repeat to cater for many millions of users. That is what is required. It is also important to be able to 'repurpose' or adapt the uses to which data is put. If we can create systems that meet a need for many users, then we have a chance of driving an adequate return on investment to attract further investment in the underpinning measurement infrastructure.

Through analytics and predictive analytics we already have really good use-cases and commercial systems that are demonstrating the value of providing Internet of Things or sensor-based data to growers, to help them make better decisions, or predict disease outbreaks, and so on. That same data can be repurposed as a service, as an app for a food safety regulator. There is an urgent need to demonstrate and capitalise the investment in and development of such systems with our partners.

Let us say we have been able to achieve this in agriculture, and now we have a flood of data. I'm not talking now about statistical sampling, but about data flows and what they make possible. The world now has much more data amenable to being handled by machine-learning and predictive analytics. We can measure variables in the environment that we have never been able to measure before, and more reliably. So whether it's PAR (photosynthetically active radiation), or leaf wetness, or UV, or temperature, or whatever it is in the environment, we can measure it, and we can put that in a very localised situation and we can understand what the conditions will be for a crop on this side of the hill versus the other side. Moreover, we can predict frost and other types of challenges for farmers, ahead of time, if we basically predict the local climate relative to the wide area data. There is a lot of thinking yet to be done but we are starting to see applications of this (e.g. Figure 5).

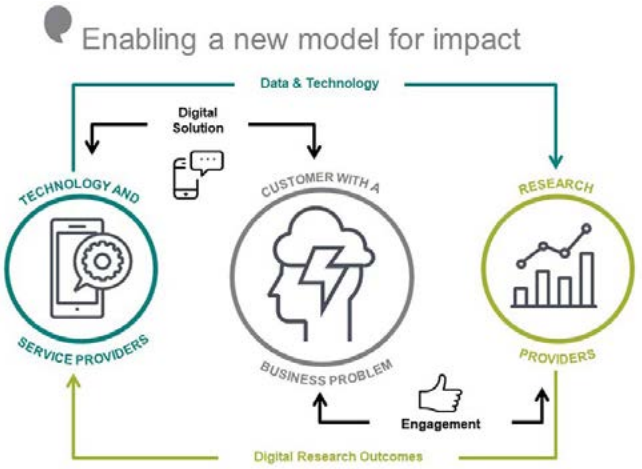


Figure 5. Making agile data science real.

Figure 6 tries to represent the agriculture–digital technology ecosystem. We believe that people sometimes take a very narrow supply-chain view. By contrast, if our CRC is developing one of these systems we would want to know how it is viewed by a producer, a processor, a retailer ... and, importantly, what happens if out of the same data system a farmer wants to provide their data to an insurer or a banker to reduce the cost of their capital and their insurance, in order to prove that they have sustainable practices. That's a different service.

An agronomy provider, an agronomy consultant, for example, can be provided a service with the same information, but perhaps from many farms. Then being able to advise and consult at a distance from the farm becomes more relevant.

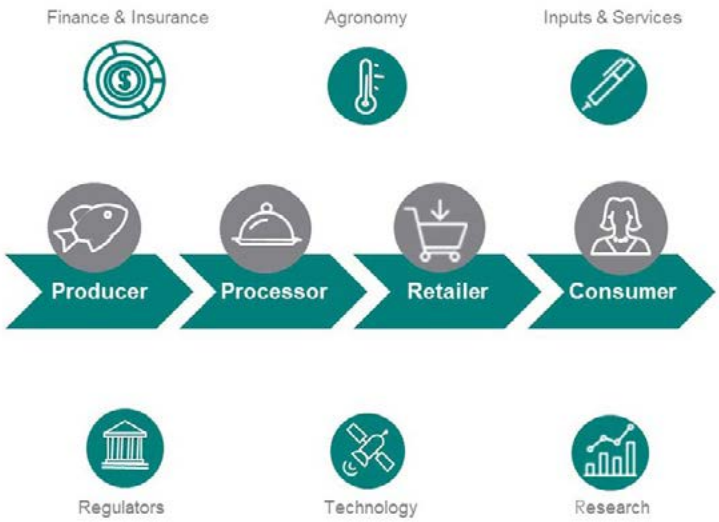


Figure 6. Attracting ecosystem investment: repurpose!

Input providers, service providers including agricultural chemical companies and so on, can provide better information, and better more targeted services, to the sector.

Research as a service: what does that look like? We have already discussed today the challenges with data and data privacy and sharing data. But what if we are able to incentivise farmers (who, we think, should maintain control of their data) to share their data with researchers so that the data can then be developed and effectively turned into an algorithm and deployed within days onto an application that a farmer can then use and validate?

The idea is that farmers and technology providers and safety regulators and others can use digital applications that are variations built on one fundamental system, for multiple purposes. Being able to repurpose that system means thinking of it not as a technology but as a service – and then central to a service must be the customer (Figure 5). Whenever I think of service I think of a little triangle: Who was that service for? Are we providing a service to a banker? Are we providing a service to a grower? What are the decisions that we want to support?

Overcoming the human barrier to digital adoption

Lastly I want to speak about deliberate innovation. This is a concept that our CRC is starting to experiment with. It is old things made new. We have borrowed concepts used in software design over many years, and also from what – in the international development world – is called 'participatory design'.

We are saying that a common big challenge is that often people do not frame a problem correctly, and then they build or find a tool that they think is going to provide the solution ... but they have not thought enough. Our approach is, in a very facilitated expert way, to gain a better understanding about the problem that needs to be solved. We do this by bringing together, in the one facilitated workshop, a banker, a regulator, a grower, a researcher, a technologist and so on (Figure 7). This is not an inward-looking focus group of people in the

Figure 7. Deliberate innovation.

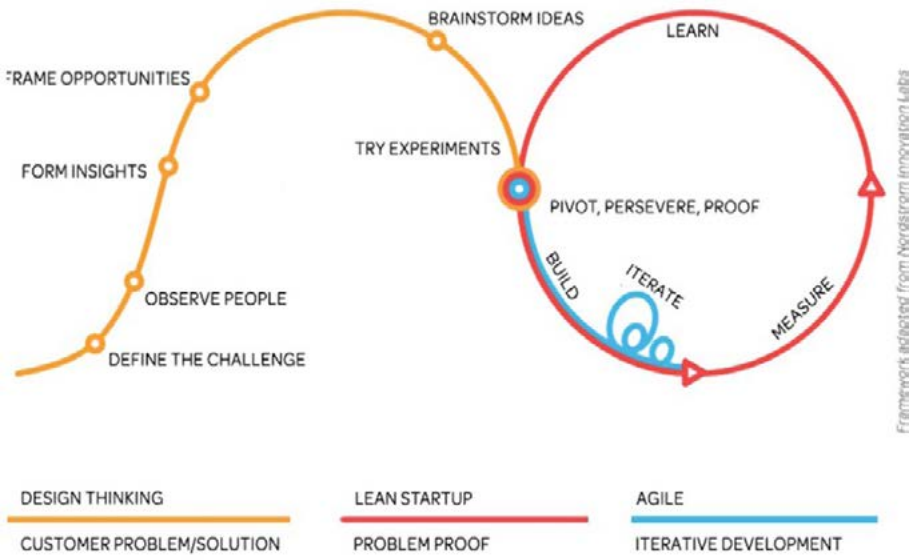


Figure 8. Customer/problem discovery and proof.

industry. Instead it is a very external reference. I think this is relatively novel and is something that the industry will benefit from – and it helps me to cross the digital divide I mentioned before, in a very experiential way.

Of course the other pattern to this is not just the framing of the problem and challenge, but also very a human thing about motivation. We've done a number of these workshops with good success, ending with the participants saying, in effect: "We understand the problem; we want to work together; we all have a different interest in this project and once we launch the project in a conventional agile model, we can then iterate it" (Figure 8). Rather than validating this with peers and so on, this is about market validation, and it's very well-known and very well understood.

What we want to do is put these things together, learn from the entrepreneur community and the start-up community, and actually apply it – not in an offhand way in agriculture, but using a professional and systematic approach which recognises the importance of diversity and trying to challenge and challenge and challenge until you intimately understand the problem that you're trying to solve.

To finish, Figure 9 illustrates the example I gave earlier about repurposing data for both growers and regulators. You can look up that use-case (about oyster-growing) if you go to the Yields website (http://theyield.com/post/barilla-bay).

I would like to add that I was very inspired by the Sir John Crawford Memorial Address last night and I think that digital agriculture can really underpin that notion of nutrition-sensitive and climate-smart agriculture.

Figure 9. An oyster-grower's example of data repurposed for a range of potential uses.

Mike was named in the Knowledge Nation 100 as Australia's chief evangelist for 'big data' and the Internet of Things (IoT) and appointed Australia's first Industry Professor of IoT at UTS. He is currently the CEO of the Knowledge Economy Institute, an IoT innovation hub, and leads the Food Agility Cooperative Research Centre to empower Australia's food industry to grow its comparative advantage through service innovation. Mike is a co-founder and Director of the Internet of Things Alliance Australia. Mike's pioneering efforts in fintech and e-research led to the global success of SIRCA and the founding of big data company RoZetta, e-research service provider Intersect Australia, and co-founding of Capital Markets CRC and AgTech business, The Yield.

Case study: Mobile on-farm digital technology for smallholder farmers

Professor Salah Sukkarieh

Australian Centre for Field Robotics, University of Sydney

Abstract

For over 10 years the Australian Centre for Field Robotics (ACFR) at the University of Sydney has been developing novel mechatronic and software systems for the Australian agriculture industry. The aim is to support farmers with the research, development and commercialisation of digital tools that would help them increase yield and productivity and reduce input costs. In 2015 the ACFR received philanthropic funding to look at designing similar technology for smallholder farmers. The hypothesis is that with an appropriate education and training program coupled with low-cost on-farm mobile platforms and digital tools adapted from more precise technology, a system and methodology could be developed that delivers food and nutrition security and encourages next-generation growers to adopt digital agriculture techniques. These requirements led to the development of the Digital Farmhand. The Digital Farmhand comprises a small mobile platform that can be hand towed, remotely controlled, or set into autonomous mode. On the mobile platform exists a smartphone, sensors, and computing. Collectively the system can undertake precision seeding, spraying and weeding. Through the digital capability of monitoring and analysing individual plants the system has the potential to support better on-farm decision making, helping growers increase yield and productivity, reduce input costs, and maximise nutrition security. The Digital Farmhand has been trialled amongst small farm holders in Australia as well as in Indonesia and will be trialled next year in the Pacific Islands. The objective of these trials is to close in on the requirements that would meet the needs of those communities.

This talk is about the technology behind the project to build the Digital Farmhand – the piece of machinery in Figure 1. The aims of the project are (i) to see how to bring together as much off-the-shelf technology as possible, both digital and physical, to try and improve on-farm production and productivity; and (ii) to look at other aspects that could aid farmers in their day-to-day decision-making.

How it began

This Digital Farmhand project grew out of a project that is introducing similar technology in the horticulture industry in Australia. The platform in Figure 2, RIPPA, is solar electric; it operates for 24 hours; it has a number of different sensors underneath – multi-spectral sensors, hyperspectral sensors, laser units. It uses machine-learning algorithms to detect individual plants (e.g. Figure 3),

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

Figure 1. Digital Farmhand – local smallholder farmer demo

Figure 2. RIPPA – Autonomous row-follower, checking on lettuce in Victoria.

Figure 3. Deep learning on lettuce plants by RIPPA.

and the growth rates of those plants. We are getting better now at determining the health of the plant as well: whether it is water stressed, for instance. We can also make yield estimates per plant. The platform uses machine-learning algorithms, and it can apply a mechanical tine to remove weeds among the crop with absolutely no herbicide at all. That is one of the objectives in this project. There is a small 'fluid shooter' that can spray fluid onto each individual plant as the platform moves along. In this case it is applying water, but it could be fertiliser or herbicide or whatever the grower wanted to add. It also checks on

the hydraulic conductivity with soil probes, as the unit moves along. In our next trial we plan to add foreign-object detection and foreign-object removal.

The platform exists because we have been funded by the horticulture industry to try and develop a system that can operate 24 hours, seven days a week and do precision on-farm mapping and also precision on-farm decision making and action in some form. This is catering for the 20–30% of Australia's growers, the big growers, who are looking for that 1–5% efficiency gain in their operations.

Catering for small growers

Two years ago we were given philanthropic funding to look at developing similar technology to support small growers. That meant focusing on three particular technologies.

The first is smartphones, but not in the way discussed so far today. We view smartphones as ubiquitous computers. They have temperature sensors, light sensors, humidity sensors, cameras on board, as well as gyroscopes, accelerometers and so on. So to us the smartphone is a beautiful computing platform with lots of sensors.

The second technology is 3D printing, which I believe is going to catch the agriculture 'wave' quite quickly, giving people the ability to manufacture any component, anywhere, to deal with a particular crop in any environment.

And the third technology is machine learning. Again our concept is unlike machine learning as only a way of dealing with data clustering. In our work, machine learning involves algorithms that give a machine the capability of making decisions in real time and, at a certain level, able to help and work with the farmer in some form.

One of the first things that we encountered as we started to talk to growers about repurposing these types of technology was their lack of digital knowledge. Therefore a key part of this program is to go into rural schools with these low-cost platforms and start to teach the kids how to use robotics, and how to code. Ideally we will show them how that applies within the food production cycle.

The other aspects of this project involve working with the Indigenous community, as well as developing-country needs.

Design and redesign

As roboticists we like to design, build, test, take it out, fail, come back, redesign and build again as quickly as possible – and go through that iteration process as much as we can. In our first iteration, all the 'smarts' were inside two tractor wheels with a cross-bar to stabilise the unit. Within 15 minutes you can piece this machine together, with a number of sensors underneath. We were interested in using the modular concept, to be able to put the device into the back of a van. That wouldn't be needed by a farmer, but could be useful to a cooperative or for going from farm to farm collecting data and information in various forms.

Figures 4 and 5 show the first iteration, the di-wheel: two powered wheel modules joined by an expandable central shaft (Figure 6). We took it from

Figure 4. First iteration of the Digital Farmhand: the di-wheel.

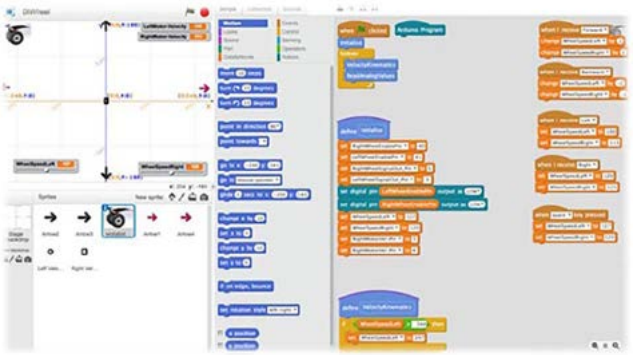
small farm to small farm around Australia, and tried it out to see what we could achieve (Figure 7). We also took it to some rural schools and were given phenomenally useful feedback from the students and the parents. To put a robot in front of these students, who have small paddocks and farms in their schools, and to be able to teach them how to code that robot within half a day to make it spray or map those paddocks, for example, is an interesting experience (Figure 8).

Figure 5. Being modular it is easy to transport in a station wagon.

Figure 6. Two people can quickly attach the expandable central shaft with its sensors.

Figure 7. Trial of the di-wheel adjusted to width to scan a row of vegetable crop.

Figure 8. (*left and below*) Demonstrating to rural schools and teaching them coding



The bottom part of Figure 8 is a user interface that allows the student to come along and just push the di-wheel forward: go left, go right. The right-hand side of the diagram, those little blocks, are real-time functional blocks that keep changing according to what the student does. So the students learn how the system is coding itself in real time as they move the device, which gives them an immediate coding experience.

The third part of this project was a visit to a developing country. We went to Bandung in Indonesia, primarily because we knew people there, and we demonstrated the di-wheel to farmers on a series of different farms. We

Figure 9. Trial on a small farm in Indonesia, with selfie stick attached to hold a smartphone taking sharp photos.

installed a little selfie stick on the top – an off-the-shelf component with a smartphone on it with internal apps for programming. The selfie stick stabilises the smartphone and you get high quality pictures (Figure 9). We also visited electronic shops and manufacturing facilities, to understand the external ecosystem in relation to maintenance and availability. It seems that farmers in Indonesia are ageing, as they are in Australia, with few young people coming into farming and little labour available. People liked the di-wheel very much. The price would be a crucial factor, and might be beyond farmers' resources.

Improving through iteration

Not many changes were needed at the next iteration. We added a three-point tow hitch to the back of the device, which means you can attach a number of different tools. Figures 10 and 11 show how an added smartphone is now able to detect individual plants, segmenting out those plants, and by the end of the row producing a plot of number of plants, size of each and a crop yield estimate. We also hooked the smartphone to the spray tank, so it only sprays target plants at the right time, not everything.

The objective now is to determine if we can build a really low-cost platform, using as much 3D printing componentry as possible. We ran a demonstration this winter with the Greater Sydney Local Land Services. About 100 growers attended, and we started to talk to them about the various concepts. It was interesting that they saw this could give them the potential to grow niche crops that could then differentiate them from everyone else, especially if the learning algorithms were working well.

Next steps: expanding understanding

With the next part of this project's funding we will go to the Pacific Islands, to three or four locations, to do a scoping study and a metric capture of how farmers would use this technology if they were to adopt it. What components would they want? For example, some farmers in Indonesia did not want the platform at all: they just grabbed the selfie stick with the smartphone and walked up and down the rows themselves, collecting data that was sufficient for their needs.

Figure 10. Improved imaging of lettuce plants, cf. Figure 3.

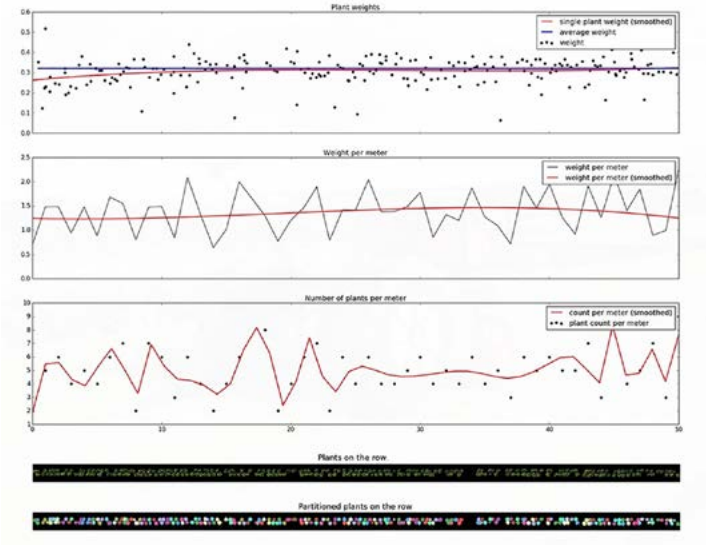


Figure 11. Yield estimates per plant from data collected along the row.

Education is another aspect of the work. In the past we have built Mars robots for the Mars Lab at Sydney's Powerhouse Museum, and had schools all over the country tapping in online to run their own Mars missions, and through that they learnt about robotics and coding. Next year we shall do a similar thing in reverse: building a few of these platforms, putting them into rural schools, and then having the student tap in to learn how to code the robotics. The teachers, rather than the kids, are the challenge here, because they need to fit these activities within the curriculum timeframe.

Smallholder farmers in Australia need training to use the platform: not just the user interface but also the physical system. We also need to learn what they want: do they need the motors, or would they just pull it along, or should it be remotely controlled or fully autonomous?

Considering the third iteration

What will the third iteration of this robot look like? Figure 12 summarises some aspects of the iteration. We are aware of the rise of the electric scooter across

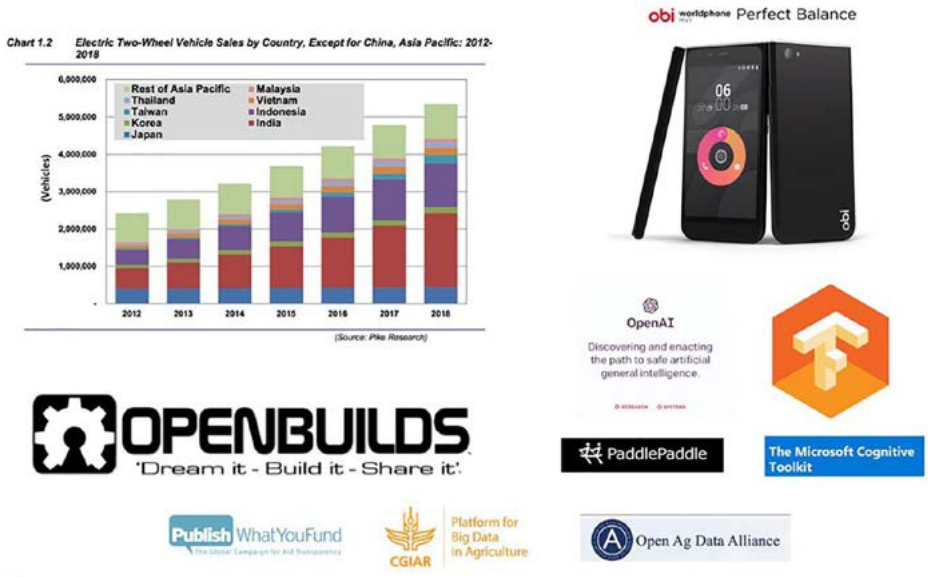


Figure 12. Digital Farmhand, third iteration. (*For chart at top left, see*: https://www.navigantresearch.com/wp-content/uploads/2012/04/ETVAP-12-Executive-Summary.pdf)

the Asia–Pacific region. If we can tap into that, and use the same battery power, motors and gear systems, then we also tap into the ecosystem that deals with their maintenance and availability. That supporting ecosystem is important. If we buy a couple of scooters and pull them apart, we can repurpose them as a tractor and then see what happens.

Have you heard about Obi? It is a world phone, built by an ex CEO of Apple who wants to see if it is possible to build high performance, high quality phones for the developing world, costing less than $200. The interest in this for me is not phone calls but that the phone is a computer with a collection of sensors on it, and if it is cheap that will help keep down the cost of devices it is attached to.

Machine learning is no longer confined to the university world. There are open-source machine-learning algorithms available for use: OpenAI by Elon Musk; TensorFlow by Google and Microsoft; and Baidu have PaddlePaddle. In other words, learning how to use these machine-learning algorithms is quite easy now. They are becoming tools; you do not have to code them before you begin. The other open-source activity that is going on is OpenBuilds, which is focusing on people who are using 3D printing and other techniques to design and build hundreds of different machines. OpenBuilds is open-sourcing that kind of activity on the web so people can then redesign and rebuild as well.

My message here is that for a third iteration of Digital Farmhand we will be seeing how much off-the-shelf software and platforms we can put together to drive it and make it low cost. It may be that there is not a commercial future in building these bots and selling them, but instead it would be better to open-source the designs so people can modify them for their needs.

Final points

We hope the Digital Farmhand will turn into a farm assistant: think of Siri (the digital assistant in iPhones) on steroids, working for agriculture. It will be a system that can offer suggestions and come back to you and show what it wants to do next. Working with a system on that very personal level becomes a very significant change, because it means being able to provide agronomy and learning continuously in real time on the farm. That is really what we are heading towards.

Second, in terms of policy, what I have seen with other industries and what I am starting to see with agriculture, is that when a policy is put in place it is often expected to hold for some years, say the next two decades. But technology is changing every few months. Therefore, it is important to be thinking about how to make policy in an innovative manner, being constantly agile.

Salah Sukkarieh is the Professor of Robotics and Intelligent Systems at the University of Sydney and is an international expert in the research, development and commercialisation of field robotic systems. Over the last 10 years he has been developing robotic and digital technologies for agriculture focusing on how technology can be used to enhance sustainability and quality of life for growers. Salah has secured a number of large-scale R&D projects from the horticulture, grains and grazing livestock industries and has demonstrated operational systems around Australia. He was selected as one of 11 LAUNCH Food Innovators, from 280 worldwide applications, for his research and technology in 2017 and was recognised as one of Australia's Most Innovative Engineers, by Engineers Australia, in 2016. Salah is a Fellow of the Australian Academy of Technology and Engineering.

Case study: Moc Chau vegetable farmers' use of data-aided decision-making, traceability, quality assurance, and access to higher value markets

Dr Pham Thi Sen

Northern Mountainous Agriculture and Forestry Science Institute, Vietnam (NOMAFSI)

Abstract

Farmers in the Son La region of north-west Vietnam are working together with ACIAR to produce high quality vegetables, supplying emerging retail markets in Vietnam. The market for high quality vegetables in Vietnam is expanding rapidly. Project farmers in Moc Chau supplied 690 tonnes of VietGAP-accredited safe-to-eat vegetables in 2016. That was 65% more than in the previous year. ACIAR projects AGB/2009/053 and AGB/2014/035 have identified the smart use of data as a key factor in helping Vietnamese farmers supply emerging retail vegetable markets. Data management has been used for:

1. Maintaining farm records. Farmers must keep records about agronomy and use of chemicals so they can trade VietGAP-certified vegetables to lucrative retail markets.
2. Value chain reporting. Analysis of vegetable input costs, prices and throughput data using specific software (MonQi® Fresh Studio) is used to inform farmers of the most profitable crops and when to produce them, and to measure their net farm income.
3. QR codes. Farmers are now using QR codes to help trace the origin of vegetable crops supplied to retailers back to the individual farms where they were produced. QR codes are ideal for developing countries because they do not require special barcode readers and software systems.

Farmers in the Moc Chau region of north-west Vietnam are working together with ACIAR-funded projects to produce high quality vegetables for supplying to emerging retail markets to improve their income. During 2011–2016 the project farmers produced and supplied almost 1,735,000 tonnes of accredited quality vegetables to Ha Noi market, significantly improving their living conditions.

ACIAR has funded four vegetable projects in the north-west region of Vietnam: two in Lao Cai and two in Son La province. This presentation focuses on only the two in Son La: projects AGB/2009/053 and AGB/2014/035. Involved in their implementation are Australian and Vietnamese institutions, including ARH (Applied Horticulture Research) and NOMAFSI (Northern Mountainous Agriculture and Forestry Science Institute) which is one of the long-term partners of ACIAR.

Paper derived from the spoken presentation, including some Powerpoint slides presented.

Figure 1: The project area, Moc Chau region in Son La province.

In 2009, from a market study, we realised that there are great opportunities for Moc Chau farmers to improve their income through becoming involved in vegetable supply chains to Ha Noi. This region (Figure 1) has advantageous conditions for temperate vegetable production also in summer (off-season) when Ha Noi and its nearby areas are too hot. Ha Noi consumers are ready to pay higher prices for high quality vegetables, and nowadays the road conditions have been improved and transportation of fresh vegetable from Moc Chau to Ha Noi is relatively easy.

However, for farmers in Moc Chau to produce high quality vegetables to supply the Ha Noi market, we need to organise them into sustainable groups and to link them to the market, because their production is very small in scale. Their vegetable plots range from a few tens to a few hundreds of square metres in area. Separately they would not be able to produce a big enough volume of vegetables for the Ha Noi market.

To this end, farmer groups need data for:

(i) vegetable production planning & volume forecast,

(ii) vegetable certification & traceability, and

(iii) cost–benefit analysis.

The data they need include:

- Individual farmer records, which include production areas and dates (sowing, planting, harvesting); fertiliser type, rate and application date; pesticides type, pest, rate and application date; and use of labour.
- Group records of each crop and harvest, which include crop type, total production (kg), date of harvest, farmer names and codes, date of delivery, and volume provided to each retailer (kg).

- Retailer and consumer data, including volumes of each vegetable crop ordered by each retailer, requirements (packaging, labels…) and feedback from consumers.

All this data is compiled and analysed such that farmer groups as well as individual farmers are able to use the information for making their production plans, and for harvesting, packaging and labelling their vegetables so as to meet the consumers' requirements (Figure 2).

The cost–benefit analysis could be carried out manually by farmers themselves or by a project partner, Fresh Studio, using the MonQi® program, developed also by Fresh Studio.

Identifying Moc Chau produce in the market

We also supported the development of the Certification Mark of 'Moc Chau Safe Vegetables' (Rau An Toan Moc Chau) and development of QR codes for traceability of the vegetables (Figure 2).

The QR code includes all information about the products, and anyone can use a smartphone or a hand scanner to scan a QR code (Figure 3). It includes the name of the household that produced the vegetable, the dates it was planted and harvested, the area (m^2) of the vegetable plot that the household planted and harvested on those dates, the name of the collector and of the transporter, the means of transportation, and even a map showing how to reach the location of the farmer group.

To use a QR code involves additional cost, and therefore at present the project farmers use two different labels. One includes the QR code and is used for vegetables supplied to retailers who require QR codes. The other label, which does not have the QR code, is used for vegetables supplied to other retailers who do not require QR codes.

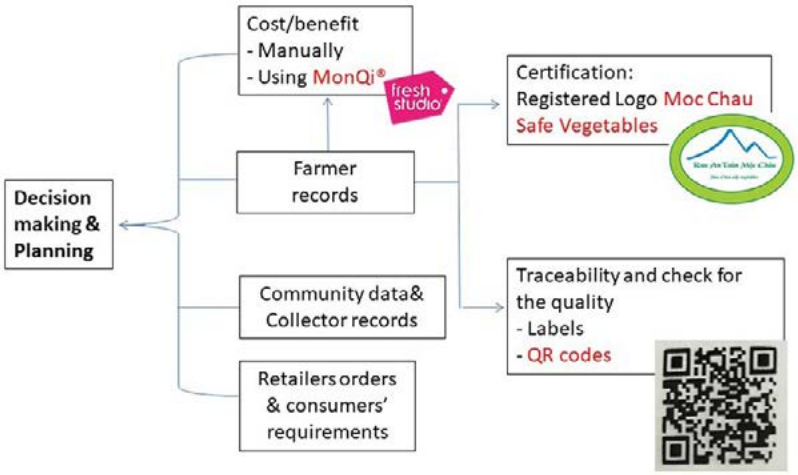


Figure 2. How the data is used.

Figure 3. QR codes can easily be scanned to identify the source of the produce.

Next steps and acknowledgement

The success of these projects has built up over six or seven years so far. The next steps are to support farmers in the effective use of the Certification Mark 'Moc Chau Safe Vegetables' to further promote and strengthen the trust of Ha Noi retailers and consumers in the farmers' products. This will involve designing, printing and managing the use of this logo and suitable labels.

We also intend to simplify the record-keeping and the cost–benefit analysis such that farmers can easily do those jobs. We want to assess the social and economic impacts, including also the impacts on gender, to see if the benefits apply to both men and women, fairly and equally. We are sharing our experience also with a college in Myanmar.

I would like to add that our project also enjoys great support from the Embassy of Australia in Vietnam, specifically Craig Chittick, the Australian Ambassador, in Ha Noi. He has visited our project site and he said he buys vegetables from our projects' farmers.

Dr Pham Thi Sen is a researcher from Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI) in Vietnam where she plays a key role in efforts aimed at sustainably managing agricultural systems, landscapes and environments in the Northern Mountainous Region (NMR), which is the poorest region in Vietnam, characterised by diverse, complex and challenging topographical, soil, climate and socio-economic features. Dr Pham Thi Sen has extensive experience in working with farming communities and local partners, and with her NOMAFSI team she has engaged in participatory R&D activities. The NOMAFSI team's goal is to restore and protect the beauty and diversity of natural resources of the NMR, while sustainably reducing poverty in local farming communities. The team has provided support to farmers in different locations to restore local rice varieties, to develop farm rice seed production and supply, to conduct participatory varietal selection, and to adopt integrated crop management, conservation agriculture, and climate-smart practices.

Q&A: Transformational change based on innovation platforms

Chair: Jane Haycock

Director, innovationXchange, Department of Foreign Affairs & Trade

Q: Caspar Roxburgh, *The University of Queensland*

Salah, I was blown away. I'm curious, how much do those two wheel robotic units that can pack into the back of a car, how much does that actually cost at the moment?

A: Salah Sukkarieh

Parts-wise they are about $6000–$10,000. Obviously that doesn't include the labour but that's what they cost at the moment. Looking ahead to using the scooters etc., you can bring them down to about $2000 or $2500, which is the objective.

Q: Bob Furbank, *The Australian National University and CSIRO*

A question for Salah. I'm a big fan of your robotics work. What kind of decision support tool are you going to convert the smartphone information into? Because there's not going to be much processing capacity to give a 3D reconstruction or a volumetric estimate, so is the output just going to tell the farmer when to harvest? Or are you going to analyse colour to tell him there's enough nitrogen nutrition? What are your plans for analysing the data?

A: Salah Sukkarieh

It's a good question, and the answer comes down to who the end user is. For a lot of the commercial applications, the bigger robots have enough computational power on board to be able to compute things in real time. And so, operationally, you collect the data and you can sit the bot on the site for the night and it processes that data; and then it knows the map and so forth, and it goes out and just does the task. With the smaller robots, yes, you have less computational power, but it's quite easy, from the software perspective, to be able to move the data to a desktop. So in Indonesia, one aspect we looked at was how you would translate data across to a desktop. We know what we would need to do but we haven't gone down that path because we're trying to understand the social implications, or what happens if you were to remove some of that decision-making process, or not remove it, etc. I don't want to explore that aspect of the work too quickly until other aspects are understood a little bit more. But from a technology perspective we'd either do it on the bot or do it on a desktop computer.

Q:

Another question for Salah. It was a really fascinating presentation. I'm interested in this kind of nexus between robotics and labour, and I was wondering if I could get you to talk a little bit more about how you see

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

something like the Digital Farmhand, or robotics generally, transforming labour in horticulture, because it is obviously a very labour-intensive industry – or traditionally has been. I'm thinking both about the labour experience of farmers that you're working with, and also of others who are involved in providing labour at different parts of the horticultural production process.

A: Salah Sukkarieh

I've been working in robotics for 25 years in different industries and I think the first time I ever received hate mail was when we started to do some stuff in agriculture. I think there's a 'disconnect' about where food comes from and from whom, and most of that hate mail comes from the public who seem to think you're putting all the farmers out of work. It was interesting because in Indonesia I got the same comments as I had in Australia: that farmers are getting older, the kids have gone off into the city and don't want to come back; it's very hard to get labour or they probably can't afford to get the labour that they're really needing at that particular point because they're competing against the mining industry and other infrastructure industries that are paying a lot more as well. So that is one aspect: that I have yet to see where we're losing labour because of robotics when it comes to on-farm activities. It's more about helping the farmer.

On the other hand, I am concerned about losing knowledge about farming, because you're digitising that process. That is why, from a policy perspective, there's a bigger social licence issue around that.

The most intense work in the horticulture industry is weeding and harvesting. We are not proposing to do anything about harvesting because they use big machines already for that. But with weeding, the intention from a robotics viewpoint could be to completely remove the need for herbicide. That really was the focus: to do that you are going back to hoeing, but you are doing it with an automated system instead of a person. But then there are big questions around that as well in different ways, and it's capitalism, not robotics, that drives that process. If farmers want to get more efficient, more productive, then what do they do? They look around at different aspects to try, and automation is one of the possibilities.

In northern Queensland, we heard a lot more about the potential impact on contract workers, and that's a significant point. When you speak to farmers they say things like: "Well you bring 'em in one day but then they disappear the next day because the guy next door is giving more money or whatever it may be". So labour availability is an issue there. It's a big question, and outside my area, but I know there are lots of those issues ahead.

Q: Alyssa Weirman, *Australian Plant Phenomics Facility at ANU*

My question also is for Salah. What kind of functional changes can you make to your machine? I'm thinking about plant researchers here. I can see that your design is centred on lettuce at the moment, but is there the capacity to raise the height of the instrument so that you can go across wheat? Is there any kind of functional capacity to change the heights of the instruments?

A: Salah Sukkarieh

Yes, one of the robots that you saw, which we call RIPPA (which stands for Robot for Intelligent Perception Precision Application), came out of a previous robot that we called Lady Bird. Lady Bird is more of a phenotyping bot which has adjustable heights, adjustable widths and so forth, and its sensors have much higher precision. It was more of a science platform, while RIPPA became more of an operational platform. Of interest here is that we built the system so that it is all modular: the wheels have their own drive trains; the sensors are plug-and-play. The idea is that you come along, see that the row is 3.5 m wide or whatever, redesign the frame to suit, and send it off to work. Everything is just modular and adapted from there.

Q: Peter Wynn, *Charles Sturt University*

Pham, I have a question to you about your vegetable systems in Vietnam. Do you integrate animal production into your smallholder vegetable production systems, and if you do, how do you recycle nutrients to ensure that the ecosystem is sustained?

A: Pham Thi Sen

Actually, in our project we have not integrated animal production into our vegetable systems. But naturally and traditionally our farmers do raise animals along with production of vegetables. The problem is that we want our farmers to produce high quality vegetables, meeting safety requirements, and so we have to support them in treating the solid waste and water from animal production. We are working on that, and we are supporting them to build some kind of system for treatment of water and waste from animal production. When the groups meet all the requirements, they will be able to get certification for safe vegetable production and then they will be able to use the logo as I mentioned, to stamp on their vegetables.

Q: Tim Reeves, *The Crawford Fund*

My question is for Mike. In one of your slides you showed a linear progression from the producer through to the consumer when you were talking about the importance of the customer. But no feedback loop. It seems to me a MAD (mobile acquired data) function would be to collect data in much the same way as TripAdvisor does for travel, getting immediate feedback. It is more difficult of course with a diverse range of producers, but have you been thinking about that aspect of customer feedback?

A: Mike Briers

Yes. I'll apologise: that slide is meant more for illustrative purposes, to illustrate the various players in the market, rather than as any linear sort of pattern. But clearly when we talk about digital disruption and intermediation and so on, we are seeing that already. We are working with some interesting players: one example is HiveXchange, on projects in rural communities, where the aim is to reduce food miles. In the north of New South Wales for example, there's a situation where primary producers are sending their produce down to Sydney for sale, and then that food goes back to markets and restaurants in the northern region. New types of platforms are emerging in a number of different

spaces, in the beef industry, in the fresh food and vegetable industry now, that enable these sorts of markets to operate. Effectively they are cutting out the middle man or woman. We are seeing all sorts of very interesting models of aggregating, where we're aggregating demand just in the mediation going on and we want to support that. Also I think there is really interesting tension between trying to produce more and focus on yield, and the conversation now about Australia being the delicatessen of Asia rather than its food bowl. How do we promote and build systems that support the types of decisions that primary producers and others make, in terms of value-adding to their product?

Q: Petra Tschakert, *The University of Western Australia*

My question is for Pham. Thank you for your presentation and thank you for showing us women in agriculture. In your experience has the introduction of data in the sale of vegetables increased or decreased gender equality in Vietnam among the smallholders?

A: Pham Thi Sen

Actually in Vietnam, we have an assumption that there is gender inequality. But so far, in our project area, we have not done any research on that and I cannot say if there is real inequality or not. However, we also intend to analyse the impact of our project on gender. Obviously now, with our support, farmers involved in the supply chain of vegetables from Moc Chau to Ha Noi earn much higher benefit. It can be 50–150% higher than when they grow other crops such as rice or maize. We would like to know, when they earn better income, does that income benefit both men or women, or does it only go to the men or only to the women? And are we creating a bigger workload for the men or for the women? Traditionally in Vietnam, women are more in charge of vegetable production, and thus we would like to see how our project affects the balance of use of labour between men and women. But I cannot say yet if there is inequality or not, nor how we will increase or reduce inequality.

Q: John Radcliffe, *The Crawford Fund South Australia*

I have a question for Dr Sen. You have demonstrated your QR codes, which provide a detailed listing of the input components of the production system for your safe vegetables at Moc Chau. But do you have an independent testing or evaluation or monitoring service that checks the credibility of that data, and do you also check the bacteriological status of the safe vegetables, particularly if they may have been grown with, say, untreated wastewater?

A: Pham Thi Sen

Yes, before we got the Certification trademark for safe vegetables from Moc Chau we had to do all the tests you mention, for chemical and for biological contamination residues in the vegetables. We also had to test for contamination in water and land areas where the vegetables are produced. But you know, because nobody can do the test for all kinds of vegetables, we have to rely on the control system for controlling the quality of agriculture, forestry and aquaculture products. We work together with them, and they come frequently or at random, to take vegetable samples to do the tests. Also, in Vietnam now there is much increased attention to food safety, and some consumers and

retailers have their own ways of testing produce. Some of them have their own way to test the quality of vegetables, and if they see any problem with chemical residues or microbial contaminants, they report back to us. Then we trace back to see from which household those vegetables came. Then we try to see where and why the contamination or the residue came about, and we solve the problem. And if the farmer doesn't want to change, to improve, then she or he can no longer belong to the group and be involved in the chain. Also, the farmer groups have their own system of internal control.

Q: Ernest Bethe, *International Finance Corporation*

I have two short questions, for Dr Sen and Professor Sukkarieh. Dr Sen, I work in countries – and I think you may be in a country like this – where there's quite a lot of fraud, food fraud, things like that. Have you begun to see anybody manipulating the QR codes? I mean are you finding that fake QR codes are going on products that are being sold to consumers? And if so, what are you doing about that?

And Professor Sukkarieh, we work with companies, large companies, that are quite concerned about the availability of agricultural labour. There are two aspects to that: one aspect is the robotics that you're talking about, and I take your point that it's not displacing any labour. The other aspect, really interesting to me, is the training that you're giving in the schools, and getting people in secondary schools more professional. That is of interest to a lot of the companies we work with – professionalising agricultural labour in a lot of these markets. Have you taken that model to developing countries? You've worked in Indonesia I know on the first part of it, the robotics, but are you also bringing the training within the schools into Indonesia, and will you take it into the Pacific, like you've done here in Australia?

A: Pham Thi Sen

We've just started to use the QR codes very recently. In Vietnam, QR codes were introduced in the end of 2016 and our farmers are among the first ones to test them. They got support from our project and they also got support from a local program for quality vegetable production of Son La province to use QR codes for their vegetables. Son La Province has a program to develop Moc Chau as a high quality vegetable production area, and our project is only working as a facilitator, supporting them to implement their own programs.

A: Salah Sukkarieh

There are a couple of things here. Industries around agriculture are going through digitisation phases. Agriculture can't afford to have people to come across from fintech, and that's really what the issue is. So from the rural schools' perspective, one reason why we're doing that in schools is that we are trying to encourage some of those children to say: "I want to stay in food production, because I find this really enjoyable with the digitisation process in there". The second reason is to introduce digital technologies into the schools and have them learn how to code, because that can affect what happens to the surrounding communities, around the farms. There will be jobs lost – we've seen that in all other industries – and although jobs get created, there are never as many as the jobs that are lost. We're trying to look at the longer-term picture.

Yes, as part of the training program, we are thinking about and have already tried to engage with NGOs in the Pacific Islands. We know that we have to introduce the training program that we've tried to develop in Australia, into that region as well. Does it go into high schools or does it go into colleges? We're not too sure yet. There are obviously going to be language issues, and fundamental education issues as well that we have to work with, and so that becomes important. The question again is – and it's the same issue as with agriculture in general – do you develop technology that helps teach, or do you try and pull the curriculum around the technology itself? The technology's growing rapidly. If you look at how any of your kids or grandkids are learning maths and so forth online now, they are not just having information thrown at them. It's about learning from your mistakes, and then having questions thrown back at you that help you improve. Is that the right mechanism? These are things that we're still looking at.

Q: *University of New England*

I have a question for Dr Sen. Food safety is a hot topic in Vietnam at the moment, and I'm very happy to know that, as I have a project to support the development of safe vegetable products in Vietnam. Can you say more about the consumer demand for safe vegetable products in Vietnam at the moment, and how much difference there is between the prices of safe and normal vegetables? What do they cost?

A: Pham Thi Sen

Actually the consumers in Ha Noi are really concerned about the safety and quality of food, not just vegetables but also other foods such as meat – beef, pork, chicken and others. And they are now ready to pay a higher price for high quality products. How much higher, depends on the products and the seasons. You see in Moc Chau we have a very cold climate in the winter, and even in the summer it is very mild, so they can produce off-season temperate vegetables. In the off-season the price is much higher, but in the in-season the price is lower because other areas near Ha Noi can also produce temperate vegetables. Also, how much higher depends on the technology you use for vegetable production. The QR codes also specify which technology is used for cultivation, harvesting, packing and transportation. The technology can be VietGAP, or safe, or organic, or whatever. So, depending on the process farmers use to produce and supply the products, the price can be a bit higher, or very much higher. But the consumers really are ready to pay higher prices for quality products.

Q: Isaac Jones, *Western Sydney University*

Pham, with the amount of information that the consumer can get from the QR codes, right down to the name of the person who was transporting those goods, could that potentially put anyone in danger or is that an invasion of privacy do you think? And how could we make sure that people are safe?

A: Pham Thai Sen

So far we have not seen any danger. We keep all records from planting to harvesting to packaging and transportation to the retailers. We are the public owner of this information and at the moment we don't see any danger. I hope there is none.

Q: David Giles, *Deakin University*

This question is about the role of 'big data' in creating or mitigating externalities and waste. It's probably mainly for Mike but perhaps for all of you. We've talked a lot today about value capture and value added. But Mike said that we can measure and record and archive more information than ever before. I'm wondering if there might be added costs involved in that, or if we're factoring in new value? Are there ways we might be factoring in new costs as well? How does it change the value or the cost of the final product? Because after all a banana is a banana is a banana, I think, but maybe 'big data' changes that? I don't know.

A: Mike Briers

Typically what we're seeing is that some of our partners, like Bosch for example, are in pretty much everything. They've got a device in every single car on the planet, and they've strategically globally said that they're going to make everything connectable to the Internet in the future. This indicates an explosion of measurement devices at one end. But at the other end of that, like so many things in tech space, the costs are reducing. And it turns out that the costs of the devices are going down, and that's really the trend: to push the cost of the actual measurement device down. The connectivity doesn't really change, because we've got different protocols now. And a lot of the data in the compute is at the edge, in the sense that it's not in the cloud which can be expensive. So I can only see that costs are going down, rapidly, and all I can see is a world full of sensors measuring attributes of the environment that we've never been able to measure before. In fact, for the decisions that matter, like disease prediction, we can actually get down to measuring exactly the attributes that we need to measure in order to predict something. And I think the value of that and having a reliable decision-support system that accurately predicts a disease outbreak on this side of the hill, that's hugely valuable.

A: Salah Sukkarieh

I have a problem with the term 'big data'. Agriculture doesn't have 'big data' compared to other industries; not yet, anyway. It may, but it doesn't have it yet. So I think we should not get side-tracked by that term. I think there's a lot of hype out there and if this was an industry conference we could talk about it as much as you want, because I know there are a lot of scientists here. What I will say is that the way machine learning and 'big data' are used, you don't worry about the hypothesis or science question up front. Instead, you see what the data tells you and then you try and evaluate something. And from my experience, what you really ought to do is to bring the two together. You still need the biophysical knowledge and then to use the data to try and capture that. So don't let go of all those methods. Otherwise, it can be garbage in, garbage out. That's what you've got to be careful about.

Chair

Thank you to all speakers in this session.

Keynote: How to digitalise agricultural systems in the developing world

Dr Andy Jarvis

International Centre for Tropical Agriculture (CIAT)

Abstract

In rural Nepal recently, lots of the smallholders I visited took selfies with me on their smartphones, sharing them on social media. Until recently, it was the other way around. It was an epiphany moment: if the tech revolution has now reached smallholders, the data revolution will surely follow. Yet the agriculture sector still lags behind in the data revolution. In the US, a recent report by McKinsey placed agriculture dead last out of 23 sectors that they analysed with respect to the extent to which they are harnessing the opportunities of 'digitalisation'. The report argues that it is no coincidence that the sectors highest in terms of digitalisation are also showing the highest economic growth (such as finance and media). For the developing world, the picture is likely even worse. Mobile money in East Africa is transforming the finance sector, yet the farmer has very limited access to digital services that help him or her better manage crops and livestock. Agriculture in Africa is only touching the surface of digitalisation – markets are largely informal, extension is face-to-face, and farm data either non-existent or completely off grid. Many of the successes of digitalisation in agriculture have been riding on the shirt tails of mechanisation – sensors on tractors is where much of the innovation is today. It is the means to gather information, rapidly analyse and adjust management, whilst the Internet of Things means the data is getting transmitted and feeding the cloud with invaluable information to better tailor precision farming. Whilst this model may be very appropriate for commercial and mechanised large-scale farming, it's not readily transferrable to the 570 million smallholder farmers in the world. Alternative visions for digital agriculture are needed, and there are a number of game-changers in the mix right now. First, smartphone penetration and 3G networks are sweeping across rural areas, and this opens a wealth of opportunities to kick start the data ecosystem. They become the node for information exchange. Second, satellite images are on the cusp of becoming fit for purpose in agriculture. Their spatial resolution can finally detect meaningful patterns in the field, and the return periods are such that we can link satellite images potentially with activities in the field in nearer real time. And where satellites struggle, drones can often do the job at limited cost. And thirdly, our analytical capacity to make sense of the dirty data that agriculture tends to generate is now greatly enhanced. By combining multiple data streams, and analysing in new ways, we can now pick out some of the critical signals to spur better decisions in the agricultural sector, be it at field level or national policy decisions. Unfortunately, a number of key impediments are still

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

> holding back a democratic data revolution that reaches the marginalised smallholder farmer. Data itself is a barrier. You need some data to be able to say something useful; yet data on site-specific farming practices, socio-economic conditions of farmers, gender-related factors and others is often hard to come by. Better use of existing data is needed to start with – open data initiatives need to be strengthened, and C:/ drives need to be liberated. Another impediment is that many of the successes in developed countries are closely tied to private sector input supplies and machinery; yet in the smallholder context such services are in their infancy, and the reach of the private sector remains limited. And an alternative service provider, public extension, is likewise severely limited in reach, with just a tiny fraction of farmers having access. There is exciting innovation in some regions (e.g. the i-Hub in Nairobi) with a boon of private sector data-intelligence-related services providing farmers with data services, but few of these start-ups reach scale, and failure rates are too high. There is also a danger of poor-quality services proliferating and giving data-driven farming a bad name. Research can help develop better open access methods, APIs [resources used in programming] to additional high quality data layers, and thus support the emerging private sector to maintain high standards of quality. The enabling environment can also be improved – greater investment in data-related agricultural R&D is needed, and training needs to be improved to develop a new generation of agronomists who are fully data- and analytics-literate. With the building of greater capacity in people and their institutions, digital agriculture can be mainstreamed into extension programs and agricultural R&D, and contribute to a stronger private sector in data-related services to agriculture. At the CGIAR Platform for Big Data in Agriculture, we have identified four areas of work that are ripe for disruption, and we are currently calling for formation of novel partnerships that combine research and agricultural development to solve some of these intractable problems. These 'Inspire Challenges' provide the opportunity to receive US$100k grants to trial out risky approaches that: 1) reveal food systems, 2) monitor pests and diseases, 3) disrupt impact assessment, and 4) empower data-driven farming. We are tremendously excited about the prospects of 'big data' in agriculture. The lack of 'digitalisation' can only be seen as an enormous opportunity. The time is now to digitalise agriculture and democratise the benefits beyond those few with a tractor, and to explore different pathways that are inclusive of the 570 million smallholders who are producing 70% of global food supply.

This talk is a synthesis of some of the emerging issues we are seeing in the digital revolution, and how we can overcome the barriers to digitalised agricultural systems in the developing world.

First of all look at this number range: 2.6 to 6.3. That is the annual average yield of maize over the last five years in tonnes per hectare in Zambia compared to Australia. These numbers show huge yield gaps, and they result from a whole range of factors: use of technology, management, soil constraints, land tenure issues, social things, extension, you name it. But some of the reason is because of use of technology and data.

You see quite often these utopian ideas of the promise of data, and the data revolution in farming. It's almost always got these elements in it (Figure 1):

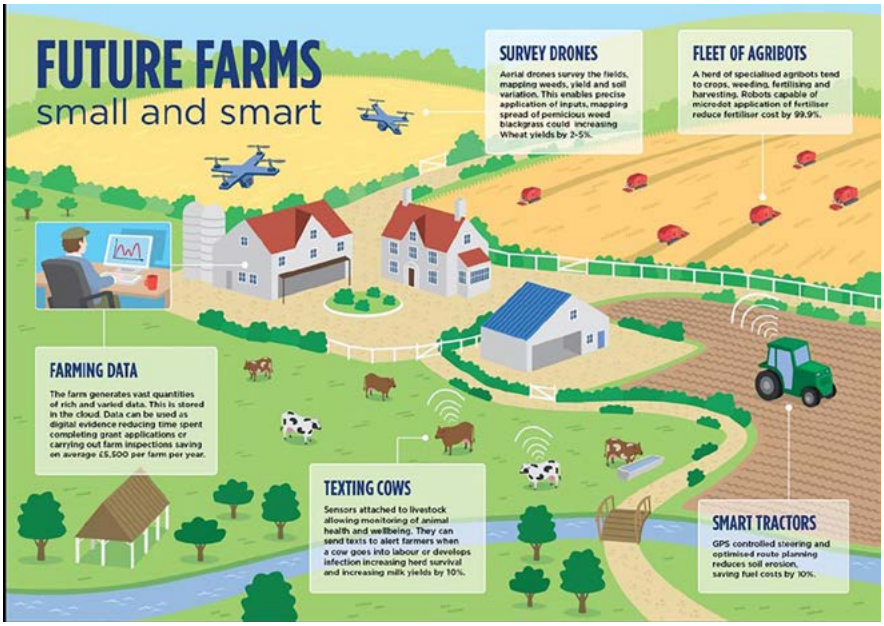


Figure 1. Ideas about the data revolution in farming – not for the developing world, however.

drones in the air, tractors transmitting, cows texting, which I think – I'm not sure – hasn't reached Colombia yet. This utopian idea is not necessarily an appropriate vision in a developing world context.

Salah Sukkarieh wowed everyone with his farming robotics. It is amazing stuff, the agri-tech world right now: it's using tractors, sensors on tractors to be collecting data and real-time decision-making. I found an example of targeted herbicide spraying, a kind of seek and spray, finding each individual weed plant and spraying just that. It figures out which is the crop plant, and then sprays everything that is not your crop. Impressive, incredible, but that kind of agri-tech is not very appropriate for the 570 million farms which are (72% of them) smaller than one hectare.

I was in a high level Silicon Valley agri-tech conference, seeing presentation after presentation of awe-inspiring use of artificial intelligence (AI) and digital technology attached to sensors on tractors, Internet of Things, and so on. And I asked the speakers afterwards, "Where do you see your business on this? How might you do this in Kenya?". And it turned out that's completely off-radar for a lot of those devices. So there's a big challenge ahead to make this appropriate for developing countries.

Moving a bit closer to smallholder agriculture, a report just came out from Mahindra Tech, looking at precision agriculture in India (Figure 2). Precision agriculture was, I think you Australians will argue, born out of Australia. Its adoption even in developed-world commercial mechanised agriculture has been slow and relatively limited. It has not been picked up as much as was hoped.

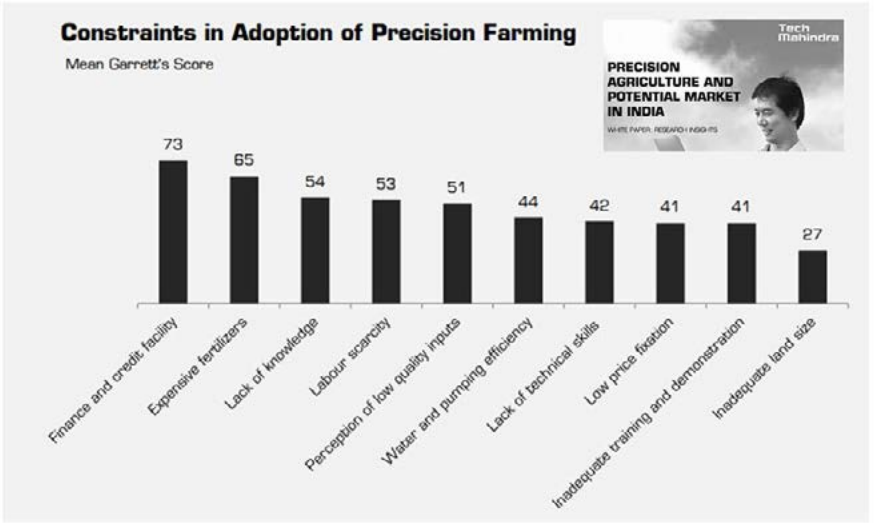


Figure 2. Constraints to adoption of precision farming in India, from the Mahindra Tech report (top right corner) *Precision agriculture and potential market in India*

For India, this report mentions a long list of constraints (Figure 2) that are still holding back adoption of precision farming. It illustrates that we really do need to be thinking about the appropriate way to bring data and digital technologies into agriculture in this context.

The McKinsey report: we saw it presented this morning by Steve Mathews, with agriculture and hunting in the US, and then Mike Briers showed it again this afternoon without the hunting and focused on Australia. To complete the picture, I have made an infographic out of it (*left*). Agriculture is number 23 out of 23 sectors in terms of digitalisation in the US – and that's in the US!

Let's think about that. Let's look instead at Burkina Faso; there it's probably number 40 out of 23 sectors. It is really lagging behind. So that's a challenge.

This is a problem in one way, but I think it is also a huge opportunity and a very exciting space to be in because I think there is a huge amount of untapped potential.

Four changes

Four major changes are happening right now that are going to make digitalisation actually easier in a developing world context than it would have been five or ten years ago.

We've talked today about the penetration of ***mobile phone technology*** across the world. Six billion people have mobile phones, and that means more people have access to a mobile phone than to a toilet! That's a real 'game changer'. A mobile phone (smartphone) becomes a node for information exchange. It is an incredible resource, and as we heard from Salah Sukkarieh it is also a sensor in itself: it's a computer on these farms.

Bringing that concept out of the abstract and into an example, I go to Nepal occasionally, and I always use my phone to take photos. And over the last two or three years I have found that I'm taking photos of people taking photos of me with *their* smartphones! So the technology's arrived. However, it has not necessarily arrived with the kind of data revolution that is supporting the business of farming. It is useful for communication, and there have been some successes in terms of market intelligence, but it is still not being fully used to potential in terms of access to data to drive farmers' decisions. We have also mentioned today the opportunities for engaging youth. Young people are naturally attracted to this technology, so, as we have noted, I think there are huge opportunities for re-engaging youth in agriculture.

Another big 'game changer' right now is ***satellites***. I have worked on a number of projects using satellite imagery. There was always a compromise: the sub-spatial resolution was never good enough; you wanted better temporal resolution, and so on. Now, I think we are on the cusp of satellite data becoming fit for purpose for agriculture, with resolution at which you can begin to see plants.

According to the Goddard Space Center, there are 2271 satellites currently in orbit, which means we can have amazing images using satellite information right now (e.g. Figure 3). This satellite technology is allowing us to monitor how,

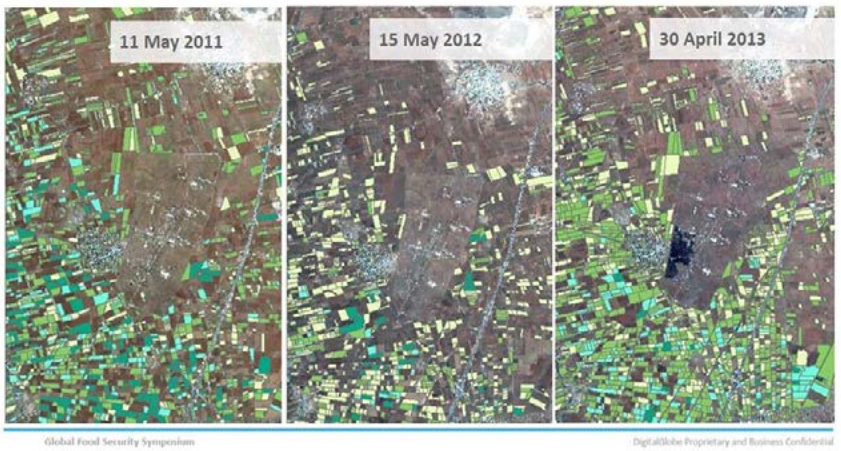


Figure 3. Satellite images mean we can compare detailed crop inventories and crop health in inaccessible areas such as Syria across years.

for example, production is continuing in Syria from year to year, and to foresee possible food security issues coming up though we can't see what is happening on the ground. I think satellite imagery offers some very exciting possibilities.

Smart cheap sensors and Internet of Things have also been touched on today in a few presentations. Not only is there an amazing amount of capability just in a smartphone, but also with a Raspberry Pi and sensors that cost one dollar you can monitor soil moisture in a field. The Ministry of ICT in Columbia is installing a system to give them 60% coverage across the country with Internet of Things connectivity. Again, this can be a total 'game changer' because now even if you cannot collect information or data from the air through satellites and drones, you can measure it on the ground relatively cheaply and effectively.

Fourthly, ***analytical capacity*** has also vastly changed. I think that capacity has always held agriculture back. It is inherently complex. There are so many variables if you are trying to understand, say, yield, and to predict yield and why, for instance, this field produced that amount of yield last season. The measurement of the variables is complex; they are 'dirty'. Agriculture is a very noisy field in terms of data analysis. While in some fields of analysis you need $R^2 > 0.99$ to claim a good fit to the data, in agriculture you are claiming victory with $R^2 > 0.4$; they can be very very noisy data sets. But now you can do amazing things using deep learning, artificial intelligence, non-parametric statistics and other new analysis tools. For example, in Mexico for a very specific region we identified data off 500 farms (this is with CIMMYT, the International Maize and Wheat Improvement Center), using information from their mass agro project, and we proposed a collection of variables that could be driving yield (Figure 4). Using new analytical capacity we were able to examine some of the relationships

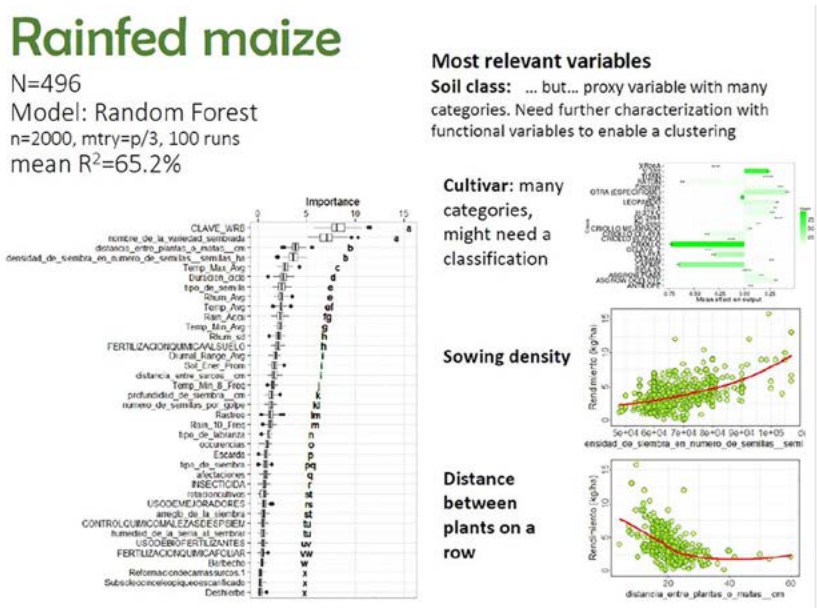


Figure 4. Using new analysis tools to analyse factors in rainfed maize yield on 500 farms, with CIMMYT.

between yield and sowing density, or distance between plants in a row, or the cultivar that was being used, or the soil information, and we could make sense out of this noisiness.

What else is holding back digitalisation?

In spite of those four game changers, digitalisation is still being held back. At CGIAR we think we have identified five of the barriers, as discussed below.

We need data to be more accessible and available. Every year CGIAR claims it surveys 180,000 smallholder farmers, but that is not done in one single survey but rather in several hundred small surveys of a few tens of farmers each. The results of the surveys take time to reach publication, and may not come out until four or five years afterwards. Meanwhile, access to the data is severely limited. All institutions have similar problems. We need to make data more available; we need to be more systematic about valuing data as a public good. That is something that will drive discovery and knowledge generation forwards. GODAN, which we heard about this morning from André Laperrière, is an amazing initiative doing a lot of work to get open data in agriculture. We need to kick-start a data ecosystem in agriculture to be able to use the data revolution for good.

Figure 5 is a kind of periodic table for open data, which was produced by GovLab in the US. It is also a range of tools and information to help drive institutional reform. It is not about individual scientists clicking and making data available; it's about putting the incentives in place and governance from the top level: leadership saying that data is crucial and needs to be transparent and open.

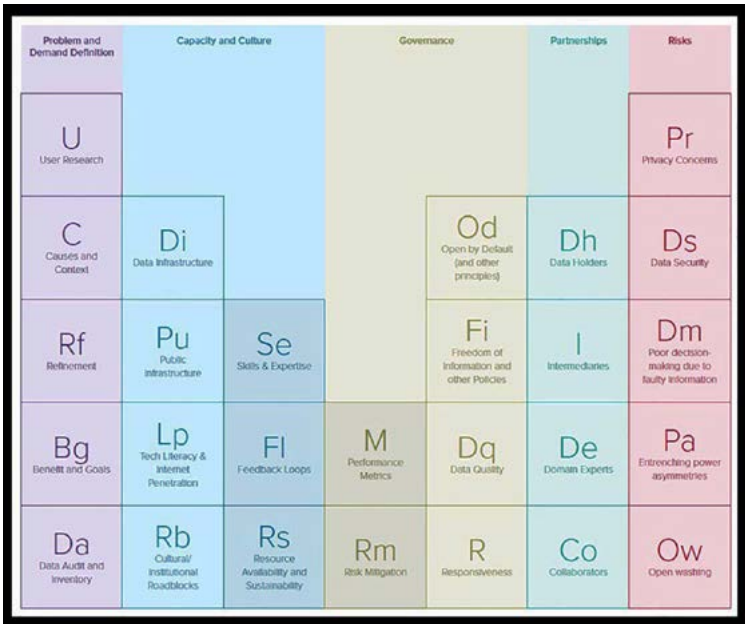


Figure 5. 'Periodic table' for open data: tools and information to drive institutional reform to make data accessible and transparent. http://odimpact.org

With that, we can kick-start a much better data ecosystem in agriculture that can say useful things.

Now, to highlight this we are going to do an interactive exercise, so take out your cell phone – does anyone not have a cell phone? There's normally one. This is your challenge: you have 60 seconds to tell me something useful that might help me make a decision in the next 24 hours. While you looking things up, I'll give you some hints: I'm staying at the Realm Hotel; I live in Colombia; I'm going to fly out tomorrow; I like sushi; I deny it but people say I like a beer. You've got another 20 seconds and you have an amazing resource in your hands, an amazing amount of information. Try and tell me something useful.

Participant: Go to Cartagena.

Andy Jarvis: OK. Did you check out TripAdvisor and it told you Cartagena's the number one thing to do in Colombia? Anyone else?

Participant: The closest place to have a beer would be the Queens Terrace Café, Parliament Drive, 88 metres from here.

Andy Jarvis: Ah, fantastic!

Participant: The Bent Spoke Brewing Co. gets 4.5 stars and it's open til midnight.

Andy Jarvis: So there we go, you see. This is why everyone has a cell phone. It's personalisation. And that's the drive of all apps right now: they can give people actionable information that is personalised. This is what's really quite amazing about the data revolution: it's not generic information, it's personalised.

Here is the next challenge: Imelda is a coffee farmer and lives in Pescador, Calca. Can you tell *her* something useful? I'm not asking you to do it in practice. This is much harder.

Personalised information for farmers: Farms and farmers in general are in the darkness in terms of personalisation. You might be able to find information about the dominant variety grown in Pescador, or at least in Calca. You might be able to get some climate information, but it is going to be very difficult for Imelda to get personalised information about how to manage her coffee, or what prices she can get around the corner in the market. But if we have open data we can start to drive personalisation of information, and once you've got that you need to set up sustained services going to famers.

One of the really clear entry points is public extension and private extension. Data can drive extension, and this will be a huge opportunity for providing farmers with actionable information instead of the 'recipe' of standard information that's given to them repeatedly on extension visits. You will be able to give seasonal forecasts: say, that the rainy season is going to arrive on this date; that you want to try early maturing varieties because the rainy season is going to be short; or that 20 farmers in this region have used *this* variety and got much better yields than with this other variety that you're using. That kind of information is potentially transformational.

The Gates Foundation with Dalberg did an analysis of the return on investment of rural digitalised advisory services. Their preliminary data showed that successful ICT-enabled rural advisory services (RAS) could drive:

- >50% adoption rates,
- 30–40% increase in yields,
- 20–25% increase in farmer income,
- 30–45 x return in farmer income per dollar invested, and
- 10 x cost savings for public systems.

They are using this as a basis for an ambitious digital agricultural strategy that they are launching now.

We need people to establish private-sector services. David Bergvinson spoke earlier about the ihub that they have set up in ICRISAT. They attract numerous young people, female and male, and a number of very exciting entrepreneurs to these innovation hubs. There is a similar i-Hub in Nairobi, and some amazing things happening there. We need to be encouraging start-ups like these, and reducing the barriers so that they become more successful. There's a danger of many of them failing because they are too expensive, and finding it too difficult to penetrate this market. Others may be providing technical information of questionable quality. So I think there's a role to be played in enabling these to be successful and to increase the quality of the types of services going to farmers.

Trust. I think David Bergvinson touched on this earlier. Trust is really crucial. For example, as researchers we often wish farmers would do what we told them to do. Consider, what is the chance of a farmer obeying an SMS text message saying: "You plant this", from an anonymous number? If the farmer is not paying attention to extension officers or researchers then they are certainly not going to take note of a cell phone instruction. We need a human interface on this. It is not just a matter of blindly sending information out. Instead it is very much about building trust in the information that's being sent to farmers. Farmers need to see it as participatory process – that information they generate is going into something which is coming back at them with added value. That human interface is really crucial for these things to be successful.

Partnerships and generating new capacity. We need a new generation of agronomists and agricultural scientists who are much more data-smart in terms of analytics. And we need new partnerships – public–private sector partnerships, upstream, downstream – linking some of the different academic departments within universities: for example, robotics (as we saw earlier today) with agriculture; electronic engineering on the artificial intelligence side of things. Figure 6 shows the range of partners we have in the 'big data' platform in CGIAR.

So those are some of the barriers and I think we have to systematically work with those in mind, aiming to overcome some of those barriers to reach the promise that is ahead of us.

CGIAR Platform for Big Data in Agriculture

The CGIAR Platform for Big Data in Agriculture has just opened this year. We have the bold goal of solving agricultural development problems, faster, better and at greater scale. We want to inject data and data-driven analyses and

Figure 6. New partnerships bring in new capacity: these are the partners in the CGIAR Platform for Big Data in Agriculture

decision-making into farming and see how can we do things differently. In some cases, that means incrementally improving things. In other cases, we want to see if we can be a bit more transformative in some of the solutions that go out there.

It's a platform by name. Everyone then asks: "What is the web address of the platform where I can get all the 'big data'?". It is not like that. It is really an innovation hub. And it is not about 'big data' but instead it is about bringing information, data streams, from multiple sources and analysing it in new ways. So it's an innovation hub by nature.

The platform has three modules: organise, convene, inspire. Under 'organise', we want to get CGIAR data and organise it, so all data being produced by agricultural science becomes findable, accessible, interoperable and reusable. The aim is to kick-start that 'data ecosystem'. If we have richer data available then, as Mario Herrero said, we don't need the dark arts to work on it; we should be able to just access information much more quickly and easily.

We need to 'convene', bringing in new partners and new partnerships. Agricultural science is not going to achieve this on its own. It needs partners that are experts in analytical informatics. It needs, on the downstream side, extension working hand-in-hand with agriculturalists, farmers and the emerging private sector around information services.

And then we need to 'inspire', to use all this and get it out, showing how it can be used in a developing country context.

In late July, we launched the 'Inspire Challenges for 2017'. As it says on our website (http://bigdata.cgiar.org): 'Our incentivized Inspire Challenges are about ensuring that information = impact. We're challenging partners, universities and others to use our data to create pilot opportunities that scale.'

The four challenges are:

- Revealing Food System Flows
- Monitoring Pests & Diseases – how can we do automated identification of pest and diseases?
- Disrupting Impact Assessment – we have a question from ACIAR, for example, "What has been the impact of ACIAR's investment in India on conservation agriculture?". Well maybe we can use satellite imagery to map out the adoption of that technology; it would be relatively quick and cheap, potentially, to do that, so there could be all sorts of interesting approaches using satellites for impact assessment.
- Empowering Data-Driven Farming – can we get more data into farming decisions?

We selected these by setting up a process to identify four topics that are ripe for disruption. In other words, we think a 'big data'-driven approach could create new insights, and solve intractable problems in new ways.

The incentives are: US$100,000 innovation prizes; 12-month grants with a minimum of transaction costs on them; we're looking for risky ideas; and we're looking for novel partnerships.

The challenge timeline is on the website, at http://bigdata.cgiar.org.

Summary

In summary, digitalisation offers huge promise. We have seen great examples today and we have heard from inspired people about some of the opportunities out there. There's really only a handful of success stories though, in smallholder systems.

I think there is plenty to learn, through iterative failing perhaps, learning about what works and how we can do it better. I think that the iteration process is important.

We need to think about appropriate technology for smallholder systems. It is a new business model, not strapping loads of sensors onto the back of a tractor, because the tractor isn't necessarily available to the smallholder farmer. We need appropriate technologies, remembering you can start with a phone and do amazing things with that.

Some of the challenges that I mentioned, such as kick-starting a sustainable data ecosystem, require institutional change.

Capacity building: we need a new generation of agricultural scientists and field agronomists.

The enabling environment for this needs to be private sector–public sector for these services to be successful.

There must be evidence of value for money, and robust impact assessment of different approaches. We will want to understand the cost–benefit of proposals. What money are you saving by doing it in a digital way rather than another way? There will need to be evidence on that.

And beyond that, there is the narrative of the impact on gender and youth. When you go searching for hard evidence on those, there is not much, so we really want to improve that as well.

Finally, this is enormously exciting, and I think this is a field that over the next five to ten years is really going to move very quickly.

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Dr Andy Jarvis is the Director of the Decision and Policy Analysis Area in the International Centre for Tropical Agriculture (CIAT), and a Flagship Leader on the CGIAR Research Program for Climate Change, Agriculture and Food Security (CCAFS), based in Cali, Colombia. Andy is also the Co-Pioneer of the CGIAR Platform on Big Data in Agriculture, a US$31m 6-year initiative to make agricultural development faster, more efficient and impact at greater scale through use of ICTs and 'big data' approaches. Andy has 10 years' experience of scientific research in developing countries to support the goals of alleviating poverty, adapting to climate change and protecting the environment. His research has focused on data-driven policy analysis on a variety of topics from agrobiodiversity conservation to climate impacts and adaptation. Over the past ten years Dr Jarvis has published over 90 articles, book chapters or books, and over 40 of these are peer-reviewed articles published in international journals. In 2003 Dr Jarvis won the Crop Science Society of America (CSSA) C-8 Genetic Resources award for best research paper stemming from his work on conservation prioritisation research for wild peanuts in Latin America, and in 2009 he received the prestigious Ebbe Nielsen award for innovative research in bioinformatics and biosystematics.

Panel Q&A: Ending hunger; 'Big data' for smallholders; Digitalising agriculture

Dr Lindiwe Majele Sibanda, André Laperrière, Dr Andy Jarvis

Chair: Professor Andrew Campbell
Australian Centre for International Agricultural Research (ACIAR)

Andy Jarvis, Lindiwe Majele Sibanda and André Laperrière in the Panel Q&A

Q: Christine Freak, *AgriEducate*
A dominant theme which has emerged during this conference has been the need for nutrition-sensitive agriculture and we've seen a shifting emphasis from quantity of production on the supply side, to the quality of consumption on the demand side. We talked last night about how this speaks to a larger recognition with interrelationships between health and environment and agriculture. Given this focus, how can agricultural development respond and, for example, do we need better conversation between nutritionists and agricultural policy makers?

A: Lindiwe Sibanda
Thank you for that question. I want to believe the starting point is all of us admitting to what we know and what we don't know. Speaking from the agriculture community, I think when we define food security I, for one, was one of those who always used to push back when the nutrition mafia would break into the room and say, "Where's the nutrition part?". And we'd say, "OK, keep them quiet; add the word 'nutrition' ", because they would insist that food security is not speaking to nutrition. We would say, "But it's speaking to production, it's speaking to access, it's speaking to utilisation, and utilisation is about nutrition – so what's your problem?". When they fought more we then added the word 'nutrition'. But from what I know now, it's not true. We didn't understand what the health outcomes are of malnutrition. To us, on

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

the agricultural side, it was, "You've got the food, you are eating it, so you are nourished – what's your problem?".

Now I can confess that I did not understand that no one food can meet the nutrient requirements of your body, there's got to be diversity. Second, I did not understand that in our quest as agriculturalists to add value, or to modernise, we spent more energy, particularly in Africa, removing the nutrients so that we have white rice, and white super-refined mealie-meal. I remember my dad used to protest, once we left the village and we were in the city, whenever we cooked our maize meal using not the super-refined type but the one from the village. He would say, "Guys, have you run out of mealie-meal?" and we'd say, "Yes, we've used the one that came from the village because we've run out of the proper one". And now I know the 'proper one' has no nutrients in it as we have not been fortifying; it was just empty calories. What it means is, it looked good, but it was devoid of nutrients.

I think these two communities – health and agriculture – need to come together, and while that is easy, there is no sector or ministry for nutrition. What that means is, within government, you can have a Department of Agriculture, a Department of Health, but nutrition falls between those two. And so it means the poor 'orphans' who are nutritionists have to understand the agriculture and have to understand the health sector.

So in the agriculture department we have to talk about nutrition-sensitive agriculture, and what that means is you can plan your green revolution projects, which are talking about yield, but you have to go back and say, 'What is the quality of the soil? Can the food that you are producing take up the nutrients from the soil? If not, when you are choosing your seeds, are you using the seeds that have been fortified, or the fertiliser that's been enhanced for the micronutrients that are not in the soil?".

There are a lot of interventions that can make agriculture nutrition-sensitive, but we've not been talking about them. For example, harvesting, storage, making sure there's no aflatoxin contamination, fortifying as we're processing the food, and also the cooking processes. On the health side they talk about health-specific interventions, and that's just adding vitamins and breastfeeding. The two languages need to meet somewhere in between; nutrition-sensitive and nutrition-specific interventions.

Q: *The University of Adelaide*
My question is to Lindiwe again. Lindiwe, thank you for your inspiring and fantastic speech last night, which reflected your belief and respect in traditional diversified farming systems and traditional agriculture. My question is, while we've had a fantastic day today learning about how digitisation can bring a revolution in agriculture, what is your advice to young people working in agriculture, so that while we go ahead and we empower and enrich smallholder farmers with digital agriculture, at the same time we maintain and we respect traditional belief systems and carry that legacy for us and for future generations to come?

A: Lindiwe Sibanda
Thank you. I'll just repeat the question: What do we say about indigenous knowledge with everything we've heard today, and what's the advice to young people in terms of the way forward?

For me, the biggest challenge is just mutual respect. As researchers, we've gone in to teach and not been honest to ourselves that we're going into the farming communities to learn. And there is a big difference! So our communities have given us the respect believing that we are the experts, and yet the 'ex' means you know nothing; you're coming to EXtractively take away knowledge which you process and publish. Maybe we should be changing the mindset and narrative to say we've come in to learn. Then people respect you and they'll tell you the truth.

Unfortunately, research for development has caused more confusion in the whole matrix, in that you will get CG System people coming along with the 4X4 truck that says 'Beans for Life'. They sit our elders under a tree and say, 'We've come here with our thousand questionnaires and we're going to ask you some questions". They know they are going to get free seed because the truck that came the previous week gave them fertiliser, and they know exactly how to respond. Farming communities have become smarter than those who think they're teaching them, because they know that 'Dams for Life' will give you a dam. If it's World Vision, if it's CIAT, they'll give you some seed, and they'll choose the farmers who are good, so that they do the experiment.

I believe we must be changing the narrative so that, first of all, we respect each other. We come with nothing; we're coming to learn. And when we learn, we'll develop a plan. Once you have a plan, when Andy Jarvis comes with his CIAT truck, you'll say, "Sorry, we don't need beans. They are not in our plan." But in most cases it has been, "We'll spoonfeed you because we've chosen this area. We want to pilot our beans here; otherwise there's nothing for you." So I think it's time for mutual respect and honesty and building of trust in terms of what we want and what farming communities need.

In terms of data, I believe the exciting thing is that very soon we'll do away with the questionnaires. We'll be able to say, "We need information." Africans now almost all have cell phones. In my village they'll even have two each, because they have one for the mobile network provider that allows them to talk from the house, and another one they use from a hill because it's got better connectivity. So now we have to go back and say, "This tool is powerful", which is exactly what we're saying here. "If you want data, this is what it will help you with – information to be better farmers."

Yesterday I spoke about Moses. Moses still plants on 11 November, because that's been the traditional planting date in Zimbabwe, Lower Gweru. Moses has no labour now because all the children now have to be educated like the cousins in the city, so it means it's him and his wife on the farm. Moses has gone to find work in the city, so it's the wife alone: the yields have gone down due to recycled seed and low fertliser use, plus many other reasons. So can you imagine going back to Moses and saying, "Come back to the farm. We'll now be able to

give you information. We'll give you loans and we'll give you insurance and we'll be able to use index-based insurance, and you'll be able to insure your assets. You don't have to sell your goats after every drought." I think that's a new narrative that will make farming attractive, and also that youth will find space in solving these complex problems.

Q: Denis Blight AO, *Visitor at ANU School of History*
My question is a historical one. Firstly, a confession on behalf of Sir John Crawford. He was Chairman of the Board of IFPRI in the early '80s, late '70s early '80s, and when the question of priorities came up, he said, "For the moment, let's give a lower priority to nutrition". So that relates to your comment, Lindiwe, on what we knew at the time. IFPRI, of course, has since corrected that approach and gives high priority to nutrition.

Now my question is to Andy. If I'm not mistaken or didn't mishear you, your presentation was predicated on the continuing existence of small farms. Are we missing a trick there? Because the Director General of IFPRI in a presentation here a couple of years ago said small farms have to get bigger and that's an inevitable consequence. Now if small farms do get bigger, if Moses sells his farm to a neighbour and that's a bigger farm, does not that assumption need a bit of adjustment?

A: Andy Jarvis
I think Mario [Session 2, this *Proceedings*] mentioned this as well. You've got a system right now where you've got – according to our best data – 570 million farms, of which 72% are smaller than a hectare. That's an awful lot of smallholder farms. So even if this kind of aggregation starts happening now, it would be reversing a trend, because at the moment farms are getting smaller and smaller as generation after generation divides the property up. So even if that reverses over the next two or three decades, I think, smallholders systems are here to stay.

It's a very active debate right now, but there's a lot of farming-system models and analyses showing that the smallholder system is highly optimised and very economically effective, efficient. So, I don't know ... I contest the idea. I think there is a lot of aggregation going on, but equally there's a lot of disaggregation going on, and I don't see in the next two or three decades that there will be a major transformation in the distribution of farm sizes. Maybe I'm wrong, but I think it's a very interesting debate.

Q: Malcolm Wegener, *The University of Queensland*
I think it's absolutely fantastic what's going on in developing countries in utilisation of technology and 'big data' and so on. In many respects they're probably even well ahead of what we're doing in our own country. I'm concerned that the development of the software is running well ahead of the development of the physical infrastructure. I guess I'm influenced largely by a fairly limited experience in Indonesia where I think farmers are close to being able to sell their coffee via their mobile phone, while the infrastructure for moving agricultural products from farm to market is abysmal. Who is going to be able to address this serious issue of improving infrastructure in developing countries?

A: Andy Jarvis
All I can do is agree. I didn't mention mobile money; mobile money is just transforming market systems! It's in incredible! But yeah, you still have to move produce. At the end of the day you can't text a tomato.

A: Lindiwe Sibanda
I can speak to Africa and the newly appointed, no longer new, Dr Akinwumi Adesina of the African Development Bank. In his commitment statement he pledged five high points. Number one is 'Light up Africa'. And that's really infrastructure. He's saying energy is the number one improvement that must happen. Number two is 'Feed Africa'. Number three is 'Industrialise Africa'. Number four is 'Integrate Africa'. Number five is 'Dignity for Africans', but really he says infrastructure is key in making it all happen ... unless we 'light up Africa' and provide energy for Africa, that energy comes with storage facilities to reduce post-harvest loss, processing to add value, and with roads! So it's in the agenda, but now it's the financing to make it happen, so at least it's not been forgotten.

Q: Bhakti Haldankar, *Agricultural science student at the University of Sydney*
Mario in the morning mentioned that small farms do have larger diversity than big farms, yet stunting and malnourishment continue. How are we ensuring that smallholder farmers not only have diversity on their farms, but also consume the diverse nutrients from that diversity? Because maybe they are growing it, but maybe selling it for the economic returns and not consuming it themselves.

A: André Laperrière
I would like to jump in on a couple of points that are related to your question and also on issues raised before. Your question, fundamentally, has to do with nutrition. It just so happens that I'm coming back from a global nutrition summit in Cambridge, where we discussed the issue of nutrition and agriculture and how to make sure we don't just produce *more* food but rather that we produce more *nutritious* food; more important, that this nutritious food is *consumed*. In the discussions we found that there are multiple angles to this question. I would for instance like to mention infrastructure, and open data of course, as key to how politicians and farmers and consumers make more enlightened food choices.

We made a review of nutrition policies across the world, and we found a wide variety, of course. There is the typical policy which turns into limiting regulations on salt content, fat content; *taxation* to discourage import or the production of unhealthy foods. Then there are *financial incentives* for people to plant the right food, or to make it cheaper, to motivate consumers to buy nutritious food versus less nutritious food. You have to look at the value chain as a whole, not just one element: otherwise you're going to produce more food that nobody will buy, or you will create a demand that will not be fulfilled.

Infrastructure matters too because you might produce very nutritious food but, as we know, 30% of the food being produced in the world nowadays goes to waste before it can be consumed, and a significant part of that loss is even before these food products get to the market. So storage, transport, taxation, fiscal incentives, customs should also be looked at since they are parts of the ecosystem that influence food consumption patterns.

To make sure that our governments put in place the right policies, there needs to be the right data, the right information, readily available and understood, which is another point that was raised earlier. Just flooding people with data doesn't work, so it needs to be massaged and adapted to its audience, be it producers, policy makers or consumers.

My last point. We're talking about small plots, small farmers. What's important is that there's a wealth of data available out there, often clouding the key information the typical smallholder farmer needs. For example, he or she needs to know when it's the right time to plant, because 'November 9' doesn't work any more because seasons' dates are shifting because of climate change. The farmer really wants to know where is the best place to buy the seeds, or where is it best to sell the tomatoes or whatever he or she is producing. So the level of information required is very clear: simple, but critical. More precisely, farmers need accurate weather and market information they can use to maximise productivity, reduce costs and maximise income. Moreover, this information needs to be conveyed in a manner that will be easily understood and in a form the end user – the farmer – will rapidly become familiar with. SMS or verbal messages are typical of that. On the other hand, governments, CEOs, researchers need and will absorb much more complex and comprehensive data and will use it for a wide range of activities, themselves leading to a number of fiscal, health and infrastructure and agriculture messages. That's what I tried to demonstrate in my presentation this morning.

Q: Tony Fischer AM, *The Crawford Fund and CSIRO*
We haven't discussed seasonal weather forecasting, which is a 'big data' problem, a massive one. I've seen recent papers taking 50 years of rainfall records, daily rainfall records, and predicting monthly totals, 12 months out, and they're doing far better than global circulation models. If we could have decent seasonal forecasts we would have a huge impact on agriculture all over the world.

A: Andy Jarvis
Wearing my CCAFS hat (Climate Change, Agriculture and Food Security), I agree climate services, seasonal forecasts, are huge. We have great experience, for example, in sending out simple information. Climate scientists get obsessed about skill and uncertainty – but farmers often need pretty simple triggers to make a right decision. Just knowing when the rains are likely to come can be transformational in terms of the management practices they can then employ. So yes, I think seasonal forecasts and getting that more dynamic information into extension and into rural radio stations is crucial. And it is 'big data'. The regional models are not performing half as well as the empirical stuff just using trends and indicators.

Q: Tim Reeves, *The Crawford Fund*
When I was Director General of CIMMYT, molecular plant breeding was just coming in. We did an economic assessment of whether we could breed more cheaply with molecular techniques and we found that it added costs to our breeding systems. It wasn't until the breeders changed the breeding systems to

be molecular-based right from the start, that it became cheaper. I'm thinking about the same thing in relation to data collection. At the moment we're adding it on; we've grown the crop and we're monitoring it and finding out lots about it and what's happening, etc. I'm thinking, a real distruption would be where you actually *design* your farming system because of data that you're able to get in real time – the measurements of soil mineral nitrogen, water, or tipping points that make you choose one enterprise or another. In other words, basing the whole farming system on data you've got *before* you begin, rather than adding on. And finding that you actually get a cheaper and better solution.

A: Andy Jarvis
Yes. Good point.

Chair
Thank you to all speakers in this session.

Closing comments: The digital revolution in agriculture

Dr Colin Chartres

The Crawford Fund

I don't intend to make a very long wrapping-up session; but I do want to make a couple of comments.

We try and pick a conference topic which is innovative and exciting and forward-looking and I really think this one has pretty much hit the nail on the head in that regard.

I was reflecting that about 25 years ago I was a scientist in Division of Soils in CSIRO and I advised our then Chief of Division that really we should be trying to put our data together. We had a lot of very valuable data on soils and water and other areas, and when we put that to many of the scientists they basically said to me, "Well, you can get lost. It's my data and you're not having it". We gradually fought through that battle and some very good technology came out of the group on digital soil mapping, where we did get that data and we extrapolated information from that data. So we made some small steps.

A few years later, I found myself as a Chief Science Adviser in the National Water Commission, and there we were trying to develop a national approach to water management. And one of the issues we had then was that the Federal Government and the states in Australia have responsibility for land and water issues. The states had most of the data on water in this case. Barnaby Joyce, our Deputy Prime Minister, this morning mentioned the Murray-Darling Basin which runs across four states and one territory, and so you need common data sources. And we had to work around this problem, because the states told us originally, "No, you're not having it. It's our data." But Ken Matthews, our then CEO, very cleverly got them to agree to a set of principles, and he went down the list: "Would you agree to this? Would you agree to that? Yes, that's wonderful. Then why won't you agree to data-sharing?". And they had no answer. So we gradually got more data together.

I think now today we can see the absolute value in having those data sets at national level, and at farm level, openly accessible. I think we've still got a long way to go, in some countries. In Asia for example, India: the water data on the Ganges is still considered a security issue and is held fairly tightly to the chest of the Indian Government. But again, releasing that data is going to be invaluable for the developers of these techniques and farmers if we're going to progress. I think we've seen quite a rapid change over the years and it all comes down really to a phrase that I've coined before and that many others have used: You can't manage what you can't measure.

We've heard wonderful examples today of that adage. If you want to manage something, you need to know the quantities, the amounts, the seasonalities, and

This paper has been prepared from the transcript of the closing comments.

then we can make progress. And we've got these wonderful technologies at our fingertips. I think if we come back in ten years' time and revisit this topic we'll have advanced dramatically further, in terms of both food and natural resources and the nutrition side of food as well as the quantity.

I also have an apology to make to you. We try and have a gender balance among the presenters. This year we failed in that regard. We've had wonderful presentations from both genders, but fewer female presenters. I put it to the young scholars in the audience, many of whom are female, and say: "Look, this is a wonderfully challenging area. You've seen the potential and the opportunities. In ten years' time if we run this kind of conference again I want to see 70% female presenters rather than the few we've had here."

Finally, I want to thank all the speakers for their inspirational and exciting presentations, and the Chairs who've done a brilliant job keeping us on or ahead of time throughout, and also our sponsors (see pp. v–vi in this *Proceedings*), and our talented and hard-working conference organising team – and you, the audience, with your keen and insightful questions.

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 to 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 during 2002–2004 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.

Highlights from the Crawford Fund Annual Conference 2017

Dr David McGill, Miriam McCormack & Dr Madaline Healey

Researchers in Agriculture for International Development (RAID)

The digital revolution has dramatically impacted our daily life, with change occurring at an increasingly rapid pace in the agricultural sector. The collection, collation, analysis and application of data digitally, has transformed global agriculture through precision technology, forecast modelling and sounder decision making along the supply chain – from demand-driven plant breeding, through food processing, to the delivery of products.

This year's Crawford Fund Conference considered what impact the digital revolution could and/or would have on the developing world. Could access to better interpretation of data and information herald improvement in agricultural productivity and profitability in these countries and Australia? The simple answer is yes. However, there is still a long way to go in revolutionising agriculture technology for the smallholder farmer, and digital mechanisms alone are simply not enough. We need to take a farm, systems and global approach. However, as stated by Dr Lindiwe Majele Sibanda in her Sir John Crawford Memorial Address, to make digital mechanisms sustainable, to make them useable and ensure they have impact, we need a new narrative. We need a new narrative for hunger, to set the tone for not just producing more food from less, but producing more nutritionally sensitive food – quality over quantity. Current agricultural systems are not nutrition sensitive: for instance, we have 800 million people hungry vs 1.8 billion people obese or sick. We need to deliver nutrition-sensitive agriculture using our global data resources.

Conference overview

The Hon. Barnaby Joyce set the tone for the conference in his opening address, saying that Australia has an incredibly honourable role to play in global food security through agriculture. During this one-day conference – which has been heralded as Australia's most significant international food security conference – this was evident.

We heard from a range of disciplines and stakeholders, sharing their knowledge, research and reason on the application of digital technology. One of the key themes of the conference was ensuring data is findable, accessible, easy to understand and, critically, allows us to make more informed farming choices. One of the challenges we face in use of global data is incomplete information, which sparked conversation around how can we obtain more robust data from growers. Born out of these discussions was the view that whilst we are all rising to the challenge of nutritional food security and digitalisation as a mechanism,

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there needs to be institutional change by government and policy to get us there. However, as stated by Dr Lindiwe Majele Sibanda, first and foremost, we need to attract youth and a new generation of agriculturalists, and bring in the technology that is required to ensure we can meet the demands of a food-secure and nutritionally-secure world.

How can big data transform small-holder farmers' lives and livelihoods?

André Laperrière, in his morning keynote address, provided an overview on where the data revolution currently sits with particular reference to farmers in developing countries and with food and nutrition security. He asked how data can be used to forecast where agriculture is going, and could go, in terms of both feeding the world's growing population and helping farmers climb out of poverty. The answer: by packaging and delivering technology in a manner that informs and translates knowledge to farmers. Data is knowledge and empowerment. We need to make data – environmental, agricultural, climatic and demographics – findable, accessible and easy to understand, and work with smallholder farmers to make use of it to make better and more informed farming decisions. Too much of the world's data is inaccessible, poorly recorded and very messy, concluding that we need to make data open and available and ensure it is used to solve real world problems.

Uses and challenges of big data for agricultural development

Speakers across the conference agreed that there is a need for guiding principles for ethical collection, ownership and use of data. However, the topic of open sources or commercialisation of data was open to debate. Steve Mathews touched on this when discussing the fact that there is no common language that industry uses to record data information. This makes it hard to understand and hard to implement on-farm in a useable format. Robust data in the right format can be developed into global solutions to provide tools for smallholders to make better decisions and more informed choices. However, currently agriculture is the least digitalised industrial sector (McKinsey Global Institute Digitisation Index) and whilst it stands to reap the most critical gains from big data, we are constrained in the large gaps in our data sets. The free market has a role to play in collating bigger and more robust data by incentivising data procurement as a tradable commodity. Steve Mathews highlighted a need to move away from a reliance on government policy and process to shape these changes and look to commercialisation. Paying for data, rather than free sharing, makes it a tradeable commodity and therefore more likely to get people to invest their data. Ask for something of value, and people should get something of value in return. A commercial model is therefore far more sustainable, in terms of producing, managing and maintaining high-quality data for profitability.

Dr Mario Herrero supported these sentiments, emphasising that it is important to understand smallholder systems and transitions in agriculture, and currently researchers are trying to fill some of the gaps, likening it to a 'black art', where the data is incomplete, old or unavailable. We need to continue to gather transdisciplinary data – economics, biodiversity, farm size and nutritional output – to compare farms across systems, globally. We are now at a point with

technology that we can use this information to create time-series data for real analysis of development impact, creating a global integrated assessment to move forward in using technology to create a more food- and nutrition-secure world. He referred to Dr Lindiwe Majele Sibanda's comments that we need a more integrated farm and global approach for food security, using nutrition as a driver for shaping supply response in agriculture. Mario shared Steve's sentiment that we need to fill this knowledge gap, but he takes a more open and collaborative approach, sharing the data, keeping it open source rather than a commodity value solution. Data is valuable, and his approach is to collaborate and share data through goodwill, with open source data a better solution.

In his case study presentation Dr Ken Street's focus was on developing rational methods for efficient data mining of our genebanks to improve plant breeding through the Focused Identification of Germplasm Strategy (FIGS). He stressed that science does not have to be complicated: it can be very simple, and we need to look for these more targeted and efficient solutions, particularly as we are limited in our resources, time and funding. Using the example of plant breeding, we need to become more effective at evaluating our enormous genetic resources to identify small subsets of germplasm that have a high probability that they will contain the plant traits we need for delivering on-ground solutions. We need to marry the simple and the super-sophisticated technologies to offer the opportunity for better crops for farmers and consumers the world over.

ICT adding value for smallholders

In his overview presentation, Dr David Bergvinson, echoing the views of other speakers, proposed that we need to attract young energetic people into extension and market integration, and part of this is harnessing the benefits of ICT in communication, which is crucial in science. He indicated that agriculture touches on all 17 of the SDGs in some shape or form and that there are many dimensions to ICT for development to benefit smallholder farmers. The importance of communicating science to farmers, community and policy makers is in attracting the next wave of agriculturalists and farmers, but we must also engage with farmers, peers, community and researchers to gauge problems and take steps to develop solutions built on these narratives.

Stuart Higgins continued this narrative in his case study, saying that if you want to solve agricultural, environmental and health problems, then engage a farmer: start a dialogue, engage and communicate. He spoke about how digital innovations, such as CommCare, are taking this principle in the other direction by providing a chance to pay the farmer back, with knowledge, in real-time, potentially providing inspiration to implement change.

The second case study, presented by Dr Andrew Mude, also stressed the importance of partnerships between the commercial sector and farmers for smallholder success, with interaction and communication key to this strategy. He said they have been running a large program with one of the companies providing insurance to smallholder livestock farmers. A key part of this is having agents understanding the products. Once-off training doesn't work: field staff need on-going interaction to keep updated and continue to develop their

skills. It is about continuing this dialogue, and continuity in training, to ensure a sustainable and effective uptake of technology and solutions on the ground.

Transformational change based on innovation platforms

Dr Mike Briers postulated that we need to use scientific data for impact and as evidence, and borrow from other industries and disciplines to rethink and repurpose innovation platforms. In discussing digital agriculture and robotics, he stressed that we need to make agriculture a knowledge intensive industry and bridge the divide between agriculture and technology. This is of critical importance, with agriculture lagging in terms of digitisation and the need to attract the next generation of farmers and agriculturalists. Agricultural digitalisation and innovation could be critical in filling these roles.

Professor Salah Sukkarieh followed on from this when discussing the situation:

> ageing workforce + children leaving agriculture = labour shortages in many countries.

He put forward the notion that building agricultural robotics can engage youth and teachers, and prepare the next generation of farmers. The robotics being developed in his laboratory represent a futuristic leap towards digitisation of agriculture and livelihoods. Robotic tractors have the potential to reduce on-farm labour and improve efficiency of input use. If a prototype can be developed at an affordable price, some smallholders may soon be working plots via a remote control.

Concluding this session, Dr Pham Thi Sen presented an example of innovative platforms delivering data-aided decision making for vegetable farmers in Vietnam. Using QR codes, consumers can trace their food back to a cooperative of farmers working to reduce their inputs to improve food safety and sustainability. The consumer is ready to pay a higher premium price for their produce, in parts of Vietnam. Diversifying the platform, in which origin of food is transparent and local, delivers another digitally aided strategy to engage with consumers and further sustain innovation of smallholder-grower market strategies.

How to digitalise agricultural systems in the developing world

Robust data that is accessible and useable; agricultural systems tailored to nutrition security and communication; extension and engagement with farmers, community and industry; developing digital technologies for sustainable smallholder development: these are some of the key themes interwoven throughout the *Proceedings* of the conference, and Dr Andy Jarvis tied them all together in his afternoon keynote address. Actionable personalised information is what we need. Extension adapted to the situations and locations of these farmers is the way to go, but it is not as simple as knowing the right information. Trust is important and is part of the equation which will help build the critical relationships needed to pass on complex information and help farmers adapt to their changing systems.

Andy reiterated what many speakers had indicated, that agricultural data needs to be findable, accessible, inter-operable and useable and we need young entrepreneurs to unlock the power of 'big data' to support farmers. There is a growing need to develop appropriate technology for smallholder

systems, particularly as modern precision agriculture and robotics may not be suitable for the 70% of 500 million farms of less than one hectare. With 6 billion people owning mobile phones, this is the game-changer for data collection and information dissemination and agricultural digitisation, but data still needs a human interface to be truly useful. He said that we need to get more systematic about valuing data as a public good, and as something that will drive innovation forward in agricultural systems.

Final thoughts

After the conference, it is time for us all to take stock and ask: What is needed to overcome impediments to successful use of big data for transforming agricultural systems? We need a worldwide contemporary agenda of the convergence of agriculture, health and environment, to digitalise agriculture and develop efficient and useable technologies, and we need to be working towards this together. We need a new narrative to bring agriculture, food and nutritional security into the digital landscape. As Dr Lindiwe Majele Sibanda said, we need a new narrative on nutrition-sensitive agriculture. We need to go the last mile into the households, as it is the most important place to go to understand the food systems better. We need to bring dignity back to the business of farming, attract a new generation of agriculturalists, and bring the required technologies along with them to deliver nutritional food security globally.

Dr Madaline Healey studied for a Bachelor of Agricultural Science at the University of Melbourne and a PhD in thrips ecology at Central Queensland University, before heading off to Laos as a volunteer and then mentor in the Crawford Fund's 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 vegetable.

Miriam McCormack is currently working as a Research Program Officer at ACIAR. In 2015 she completed a Bachelor of Agricultural Science (Honours) at University of Tasmania, Hobart. Her honours thesis focused on the knowledge transfer and technology adoption of smallholder beef farmers on the south central coast of Vietnam. Miriam is interested in farmer decision-making and motivation. This year her work is focusing on gender and agricultural extension in international research for development projects.

Dr David McGill completed a Bachelor of Agricultural Science degree at the University of Sydney and his PhD at Charles Sturt University working on quantitative genetics. Over the last eight years David has been the project manager/leader of an ACIAR project working on improving smallholder dairy production by working with local extension and research departments. In early 2016 David started working at the University of Melbourne in an international R4D role in animal production. His interests range widely, from genetics and epidemiology to impact assessment using the big data that can be captured using mobile technology. David maintains strong links and partners from time he spent in Pakistan.

Conference delegates 2017

*Conference scholars are marked with an asterisk

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ANU = The Australian National University.
ACIAR = Australian Centre for International Agricultural Research

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*Sarwar, Salman	The University of Queensland
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Wegener, Malcolm	The University of Queensland
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Wynn, Peter	Charles Sturt University
Yargop, Rohan	The University of Adelaide
Zalcman, Emma	Ausvet Pty Ltd
*Zeb, Tahseen	Tasmanian Institute of Agriculture
*Zhang, Yanchen	The University of Adelaide

Conference media coverage 2017

In date order

7 AUGUST

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Resonate Regional News QLD from Radio release – coverage across 13 stations

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Ballarat Voice FM from Radio release

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – National Rural Comm Network – multiple locations from Radio release

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Hobart Hit 100.9/Triple M – from Radio release

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – AIR National News – from Radio release – coverage across 92 stations

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Nth Qld Local radio from Radio release – coverage across 5 stations

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Albury/Wodonga 2AY – from Radio release

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Bendigo & Castlemaine KLFM VIC – from Radio release

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Gippsland (Cooma) – Capital Radio– from Radio release – coverage across 3 stations

8 AUGUST

Dr Ken Street — 'High tech methods unearth ancient crop secrets'
http://www.theaustralian.com.au/news/health-science/high-tech-methods-unearth-ancientcrop-secrets/news-story/b6e9d15ab0ac0c55cb90e42c07c682db
Print/online – *The Australian*

Dr Lindiwe Majele Sibanda
'Drought, long-running conflict bring on brutal food crises in Africa'
http://www.abc.net.au/news/programs/the-world/2017-08-08/drought,-long-runningconflict-bring-on-brutal/8787538
Video, 5m36s
TV – ABC News *The World*

8 AUGUST *continued*

Dr Andy Jarvis — Radio – ABC Canberra – live

Dr Andy Jarvis — National rural news
http://www.2gb.com/podcast/national-rural-news-august-8/
From 3m56s to 4m30s and again at 11.55
Radio – 2GB Radio National Rural News

Dr Ken Street — 'Sought after seeds could be our saviour'
http://thewire.org.au/story/sought-seeds-saviour/
Radio – The Wire – National Current affairs across Community & Indigenous Radio

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Nth Qld Rural from Radio release
– coverage across 5 stations

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Sydney 2SM (Super Radio) from Radio release
– coverage across 38 stations

Dr Ken Street — 'On the Hunt for Future Crop Solutions'
Radio – Kingaroy – Crow FM

9 AUGUST

Herrero, Mathews, Ritman, Sibanda, Laperrière
'Data for a food secure world: Takeaways from the Crawford Fund annual conference'
https://www.devex.com/news/data-for-a-food-secure-world-takeaways-from-the-crawford- fund-annual-conference-90843
Print/online – Devex.com

Dr Andy Jarvis, Dr Herrero
'Big data to deliver food security through smart device revolution'
http://www.farmonline.com.au/story/4843167/how-to-tap-tech-and-feed-a-hungry- world/?cs=5376
Print/online – *Farm Online* (Fairfax Regional)

Dr Andy Jarvis, Dr Herrero
'Big data to deliver food security through smart device revolution'
http://www.stockandland.com.au/story/4843167/how-to-tap-tech-and-feed-a-hungry- world/?cs=4582
Print/online – *Stock & Land* (Fairfax Regional)

Dr Andy Jarvis, Dr Herrero
'Big data to deliver food security through smart device revolution'
http://www.theland.com.au/story/4843167/how-to-tap-tech-and-feed-a-hungry- world/?cs=4582
Print/online – *The Land* (Fairfax Regional)

9 AUGUST *continued*

Dr Andy Jarvis, Dr Herrero
'Big data to deliver food security through smart device revolution'
http://www.queenslandcountrylife.com.au/story/4843167/how-to-tap-tech-and-feed-a- hungry-world/?cs=4582
Print/online – *Queensland Country Life* (Fairfax Regional)

Dr Andy Jarvis, Dr Herrero
'Big data to deliver food security through smart device revolution'
http://www.stockjournal.com.au/story/4843167/how-to-tap-tech-and-feed-a-hungry- world/?cs=4582
Print/online – *Stock Journal* (Fairfax Regional)

Stuart Higgins
http://www.abc.net.au/news/rural/programs/nsw-country-hour/2017-08-10/nsw-country- hour-wednesday-9-august-2017/8792648
13m35s – 20m30s
Radio - *NSW Country Hour* (possibly others)

10 AUGUST

Mario Herrero — Q&A: CSIRO on big data to support the SDGs
https://www.devex.com/news/q-a-csiro-on-big-data-to-support-the-sdgs-90850
Print/online - Devex.com

Stuart Higgins — 'Former farmer looks to improve agriculture in developing nations using technology'
http://www.abc.net.au/news/rural/2017-08-10/former-farmer-looks-to-help-farmers-in- developing-nations/8790044
Radio/online - ABC Rural

Andy Jarvis
http://2ser.com/episodes/on-the-money-700pm-10th-aug-2017/
Approx 10 minutes into 30m segment. Interview runs for 9m30s.
Radio – "*On the money*" National Community Radio

Stuart Higgins — 'New data harvesting system can help Pacific farmers says researcher'
http://www.abc.net.au/news/programs/pacific-beat/2017-08-10/new-data-harvesting- system-can-help-pacific/8794668
4m34s (NOTE: Expires 08/11/17)
Radio – Radio Australia *Pacific Beat*

11 AUGUST

Andrew Campbell	Q&A: Bringing Australia's 'best kept secret' on food security into the open https://www.devex.com/news/q-a-bringing-australia-s-best-kept-secret-on-food-security- into-the-open-90853 Print/online – Devex.com

12 AUGUST

All	Conference 'whip around' http://www.raidaustralia.net/index.php/component/k2/item/684 Print/online – RAID Australia

THE CRAWFORD FUND
For a Food Secure World

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

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