Keynote: How to digitalise agricultural systems in the developing world

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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):

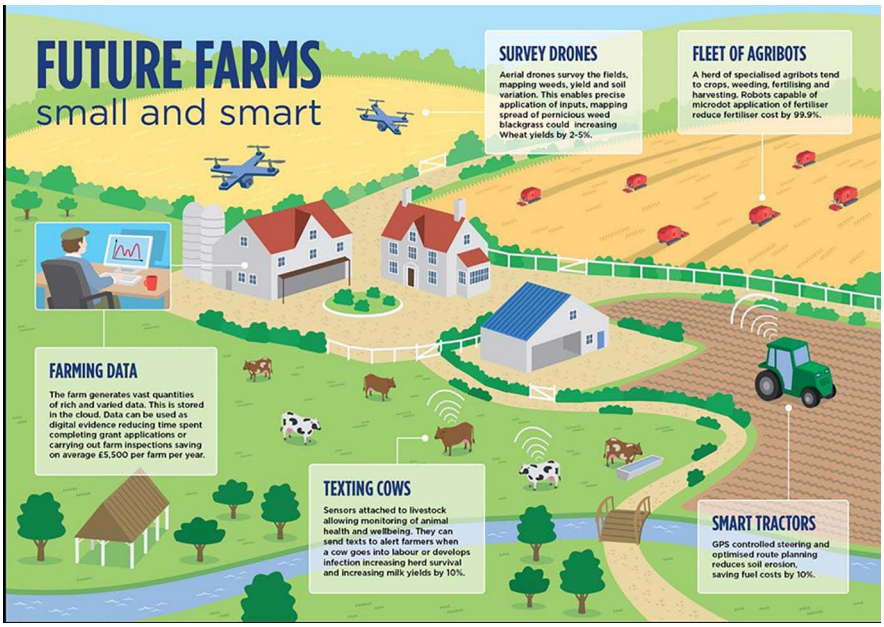

Figure 1. Ideas about the data revolution in farming – not for the developing world, however.

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.

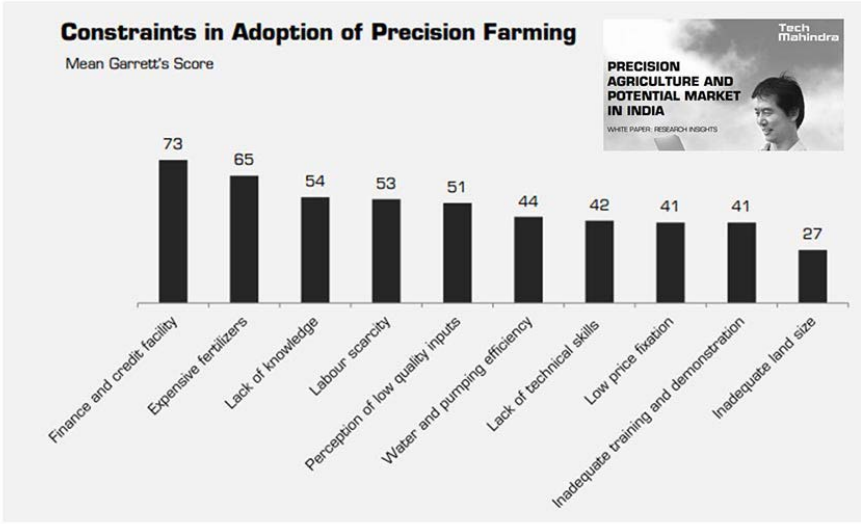

Figure 2. Constraints to adoption of precision farming in India, from the Mahindra Tech report (top right corner) *Precision agriculture and potential market in India*

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,

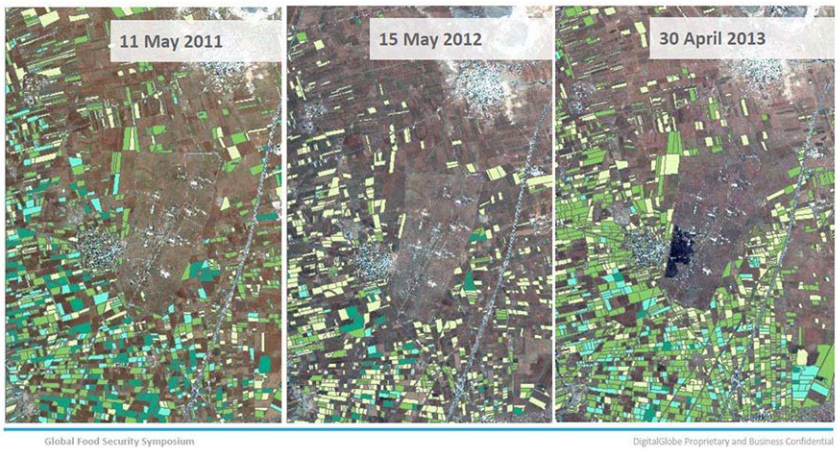

Figure 3. Satellite images mean we can compare detailed crop inventories and crop health in inaccessible areas such as Syria across years.

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

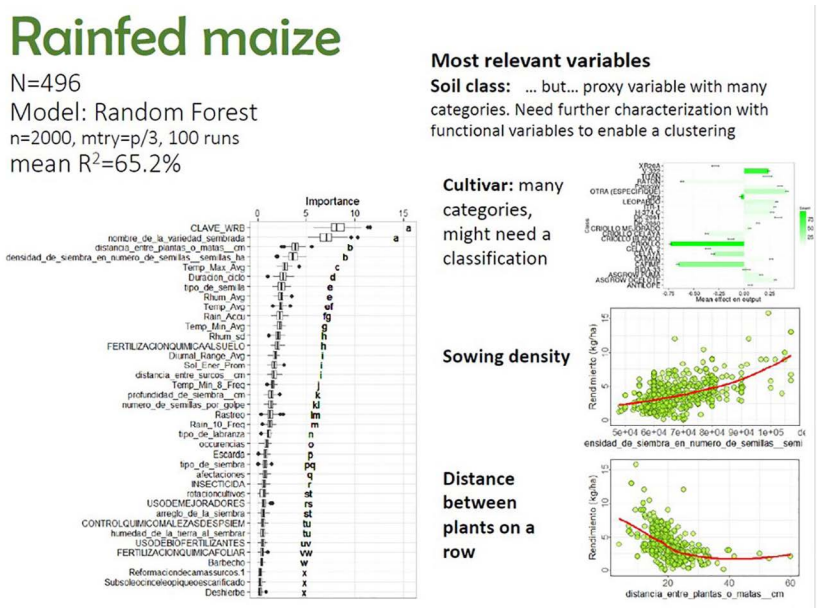

Figure 4. Using new analysis tools to analyse factors in rainfed maize yield on 500 farms, with CIMMYT.

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.

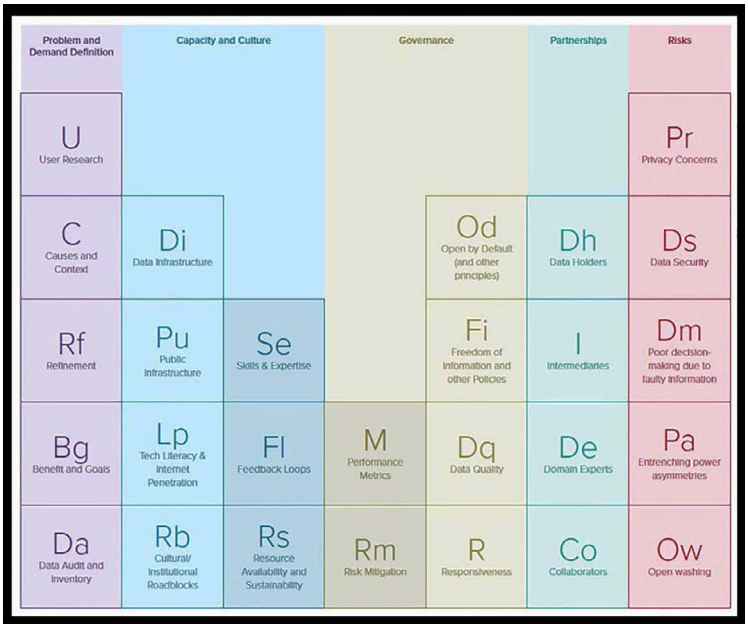

Figure 5. 'Periodic table' for open data: tools and information to drive institutional reform to make data accessible and transparent. http://odimpact.org

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.

References

Tech Mahindra (2017) Precision agriculture and potential market in India. White paper: Research insights. https://www.techmahindra.com/sites/ResourceCenter/White%20Papers/New_Gen_Services/PrecisionAgriculture-PotentialMarket-India.pdf

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