Threats to global food systems from biosecurity issues

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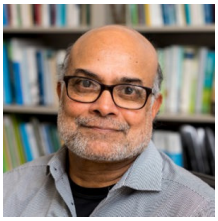
ABSTRACT



Global food systems have gone through periodic transformations over the past sixty years: the Green Revolution, the Livestock Revolution, and the globalisation of food trade are some of the epochal events observed. The nature and magnitude of biosecurity risks have evolved with the rising intensity and complexity of agriculture and food systems. While transboundary crop pests continue to challenge global food security, zoonotic diseases are rising as risks to human health. The global movement of goods and people has further expanded biosecurity risks, in terms of scale and intensity of impacts. Rising global temperatures will further exacerbate the risks associated with transboundary pest and zoonotic diseases. COVID-19 provides an important example of food systems impacts from a global health shock. Policy and management opportunities for managing biosecurity risks and rebuilding food system resilience need urgent assessment and global action.

Today I want to talk about food systems transformations and biosecurity threats. As we all know, biosecurity threats are threats through plant pests and plant diseases and animal diseases, and they have been around throughout history. But what is important for us to recognise is that the incidence of these threats, the frequency of these threats, the magnitude of these threats have dramatically increased over the past half a century or so; and they have increased as food systems have changed and as food systems have transformed themselves. That is the subject of this talk: the way in which food systems have transformed, and how pests, diseases, animal pests, plant pests, and zoonotic diseases* have evolved over time, along with these transformations in food systems.

When I think about food systems transformations, I think about them in terms of four distinct periods. First, the two decades starting in the 1960s when much of the world was focused on hunger reduction and improving food security, and doing that through improving staple crop productivity: the famous Green Revolution – the Green Revolution in rice and wheat.

The second big period for food systems change happened as a consequence of the Green Revolution, with the growth in incomes; the way in which agricultural growth led to structural transformation, and kickstarted overall economic growth, especially in Asia; the rising middle-class populations, urban

This record has been prepared from a transcript and the slides of the Zoom presentation.

* Zoonotic diseases/zoonoses – diseases that can transfer from vertebrate animals to humans (WHO).

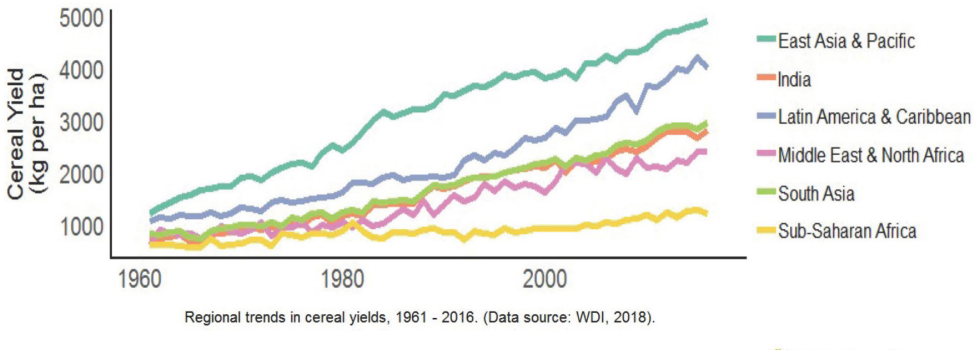


Figure 1. Global trends in cereal yields 1960–2016.
Data source: World Development Indicators 2018.

populations; and how all of that resulted in changes in demand for food, changes in demand for diversity of food, especially animal-source foods.

The third big period started around 2000 with the signing of the World Trade Organization agreement on agriculture, and the opening up of food markets, and the broad integration of food trade around the world. At the same time there was increased homogenisation of consumer tastes, which had consequences for food and food systems.

The fourth period is today, where we are looking at food and food systems in relation to environmental degradation, in relation to human health consequences, and at this nexus between food, health, environment and climate, etcetera.

All these changes in food systems have also brought about changes in biosecurity, and that is the big message from my talk today.

Green Revolution (1960–1980) focus on reducing hunger and growing staples

The Green Revolution, as we know, has had tremendous impact on overall productivity of staple grains. Figure 1 shows very clearly the change that has taken place in productivity in regions of the world that went from being desperately food insecure to becoming food self-sufficient, and in many cases becoming export-oriented economies and exporters of food. The exception is sub-Saharan Africa, but even in sub-Saharan Africa more recent trends show more positive changes happening to food security.

There have been many unintended consequences of the Green Revolution, and we know many of them in terms of environmental degradation, water pollution, biodiversity loss, etcetera, but we do not spend enough time connecting the Green Revolution and the intensification of agriculture with the problems of transboundary pests and transboundary pest infestations. The intensification of transboundary pest infestations happened as the Green Revolution happened, and as the Green Revolution changed the overall food systems across the world, particularly in the developing world.

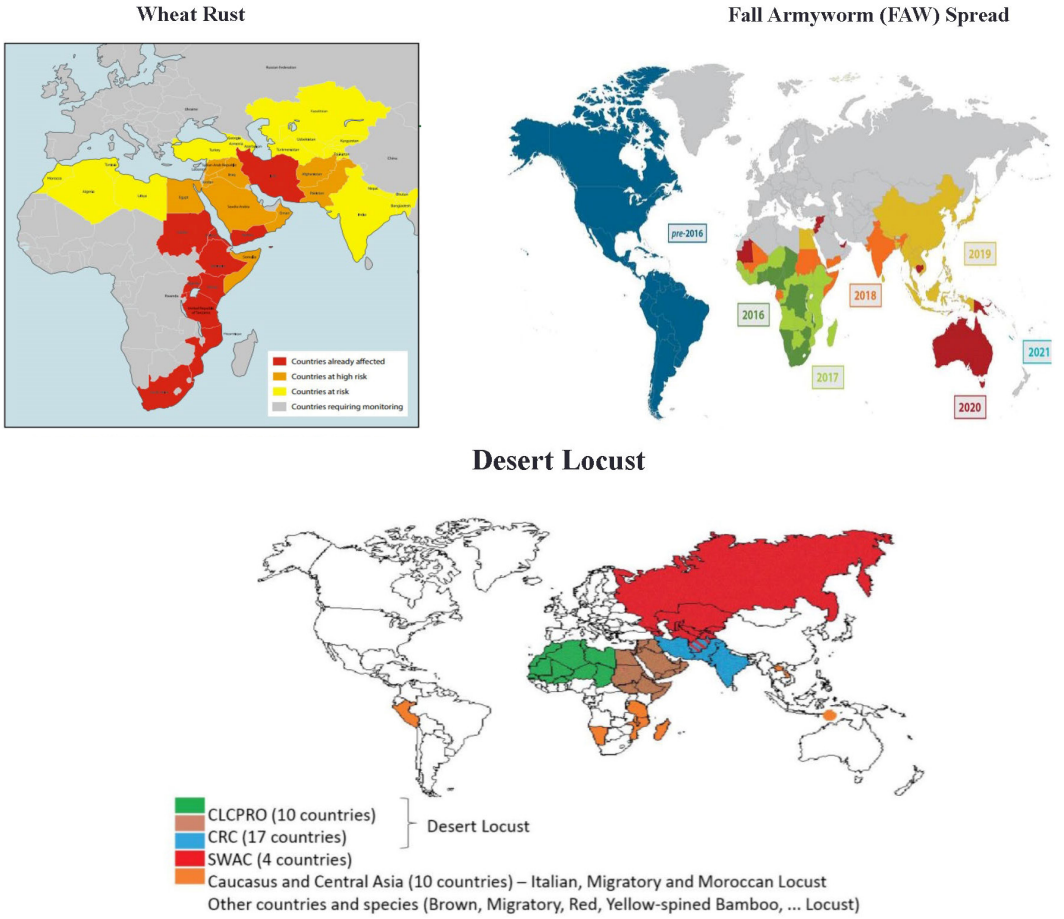


Figure 2. Geographical distribution of transboundary pest infestations. *Source:* FAO.

wheat rust Ug99 – https://www.fao.org/3/i3730e/i3730e.pdf
fall armyworm – https://www.fao.org/fall-armyworm/monitoring-tools/faw-map/en/

Figure 2 shows some examples of some of those effects. Wheat rust spread rapidly across Africa and through the Middle East and into India. Wheat rust Ug99 has become one of the major pest problems for wheat, and the spread has happened primarily because of increased homogenisation of the wheat crop. Very similar varieties are being grown very intensively across the wheat growing regions, spreading across from the Middle East, all the way into South Asia and into northern parts of Asia.

Similarly, we see the spread of fall armyworm for maize, and you can see the way in which fall armyworm spread from Africa towards South Asia, and then to the other parts of Asia, and now into Australia (Figure 2). That spread has happened because of similarities in the crops grown, and also because of the increased trade, increased movement of commodities that has happened through globalisation. Another example is the spread of desert locusts

Table 1. Predicted economic losses.

Pest	Estimated annual loss	Crop or region affected	Source of information
Wheat rust	~$3 billion	wheat	CIMMYT
Fall armyworm (FAW)	$4.6 billion	maize	FAO
Brown plant hopper (BPH)	$300 million	Asia, especially SE Asia	
Total plant diseases	>$220 billion	global economy	World Economic Forum
Invasive insects, such as desert locusts	≥$70 billion		World Economic Forum

(Figure 2). The spread of desert locusts and the effects they have had on agriculture are very visible and often shown on TV news programs, especially affecting the poorest countries in Africa.

Losses

There have been several estimates of the losses through transboundary pests (Table 1). For wheat rust, losses are around $3 billion per year, and close to $5 billion for fall armyworm. Brown plant hopper is a major pest problem in Asia, especially in South East Asia, resulting in losses of around US$300 million annually. The World Economic Forum reports that the total costs of plant diseases amount to around $200 billion around the world, and that costs from invasive pests and insects like the desert locusts amount to at least $70 billion per annum.

As a global community, we have been facing those phenomenal losses that happen because of transboundary pests, and the challenges of trying to manage them especially in smallholder systems, for the past three to five decades, and we have not been able to manage these losses successfully in a way that is sustainable or that creates more resilience in these systems.

1980–2000: rising incomes and food diversity

The second period, from the 1980s up to, say, 2000, was a period of rapid economic growth especially in Asia. There was rapid growth in middle class populations and incomes, and rising demand for food diversity. Figure 3 shows changes in diets, between 1970 and 2018, for Bangladesh, India, Thailand, Malaysia and China. Across the region, per capita consumption of staple grains dropped (mid-blue bars in Figure 3), while at the same time consumption of non-staple food groups started to rise. There was particularly more consumption of livestock products such as meat, milk and eggs (green bars), and also in vegetable products and fresh fruit (yellow, orange, grey bars). These changes happened as incomes grew, and it is interesting that similar changes and trends have been fairly universal not only across Asia but also in other parts of the world, including Latin America and more recently in sub-Saharan Africa.

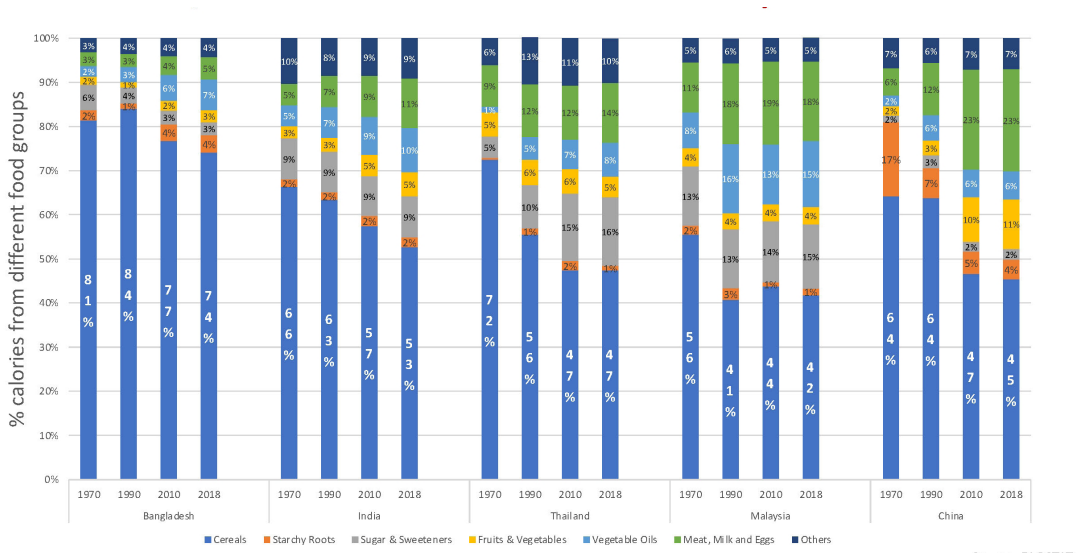


Figure 3. Diversifying of calorie sources: less reliance on cereals over time; increase in consumption of meat and fruits and vegetables. *Source:* FAOSTAT.

As demand for livestock products grew, so overall livestock populations increased around the world (Figure 4). There has been rapid rise in poultry and a steady rise in sheep and goats and cattle. Livestock systems are not only the large-scale organised industrial production systems, but also the smallholder systems with, say, a few cows, a few chickens, because that is where the growth has happened – and where many of the risks in biosecurity begin.

Unless we address these risks in the smallholder systems, we will not get on top of biosecurity risks broadly.

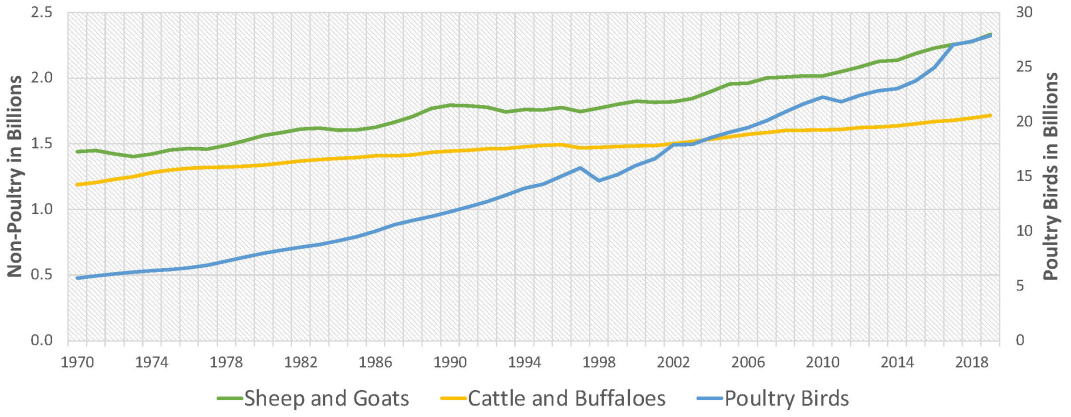


Figure 4. Phenomenal increase in the total number of livestock over the past 5 decades: global livestock populations over time. *Source:* FAOSTAT

The risks have been significant. Since the livestock revolution, the diseases linked to livestock have also risen quite significantly. The frequency of foot-and-mouth disease (FMD) has risen, as have the big impacts of foot-and-mouth disease across the world. There were outbreaks for example in 2005 in China, in 2007 in UK, and in 2010–2011 in Japan and South Korea. Foot-and-mouth disease is estimated to have caused at least $6.5 billion of annual losses. Similarly, mad cow disease (BSE, bovine spongiform encephalopathy), with multiple outbreaks in the 21st century, has become a major concern in the way it affects cattle and also human lives.

Avian influenza has been in the news several times in the last couple of decades, and it has been one of the major zoonotic diseases of concern to us as a global community (Figure 5). There have been numerous outbreaks in the recent past: it has been a particularly big problem in Asia, and has also affected the Middle East and Europe. In Asia, avian influenza is estimated to have cost around $10 billion; during the height of the infection up to 200 million birds either died or had to be culled. That had a significant impact on the livestock industry and on livestock producers, especially smallholder producers in the region.

2000–2020: globalisation of trade and consumer tastes

After the year 2000, the borders for trade were removed and there was significant global integration of food trade. Food markets expanded dramatically across the world. At the same time, consumer tastes changed and became more Westernised, more globalised and more homogenised. There was increased consumption of a wide variety of imported products, and we saw a very close relationship between the rise in food imports and the spread of invasive species: pests, diseases and weeds spreading through trade and food commodities that were brought in from other countries. To give you an idea of the magnitude, 77% of the invasive species pests in tropical Africa in the last 25 years came in through trade. For the US alone, economic losses from non-native species account for around $162 billion annually, and globally that number would be scaled up five or six or 10 times.

An important point is that although invasive species have always spread around the world throughout history, today the spread is significantly faster because of the fast movement of commodities and people around the world. Therefore, a common question is: Shouldn't we be going local in terms of our food systems? And shouldn't we be going organic?

It turns out that there is a case to be made for local food systems being more resilient to market disruptions and pandemics, but for organic food it is not clear that the connection with pest problems is negative. It is not clear that if you switch to organic food you will see less pest damage or pest infestation or transboundary pest risk. Studies have shown that organic produce is just as susceptible to harmful pathogens such as *E. coli*, *Salmonella*, etcetera. Studies at Kansas State University show there is no difference in the prevalence of *E. coli* between organically and conventionally raised cattle. There have been similar studies that look at vegetables, fruit and other products. So organic by itself is

Figure 5. Countries affected by avian influeza H5N1 beween 2003 and 2008.
Source: FAO and WHO.

not the answer: you still need to have safe production systems even when you look at organic systems.

Now: the food, environment, climate, human health nexus

In the years I have been an agricultural economist, since 1982, I have never seen as much interest in food and food systems as there is today. One reason for the interest is because food is seen as a reason for several environmental problems and human health problems, and as contributing to climate change. At the same time, food systems are also seen as part of the solution.

That interest in food, trying to address and solve the problems, is very welcome and something that we need to build on.

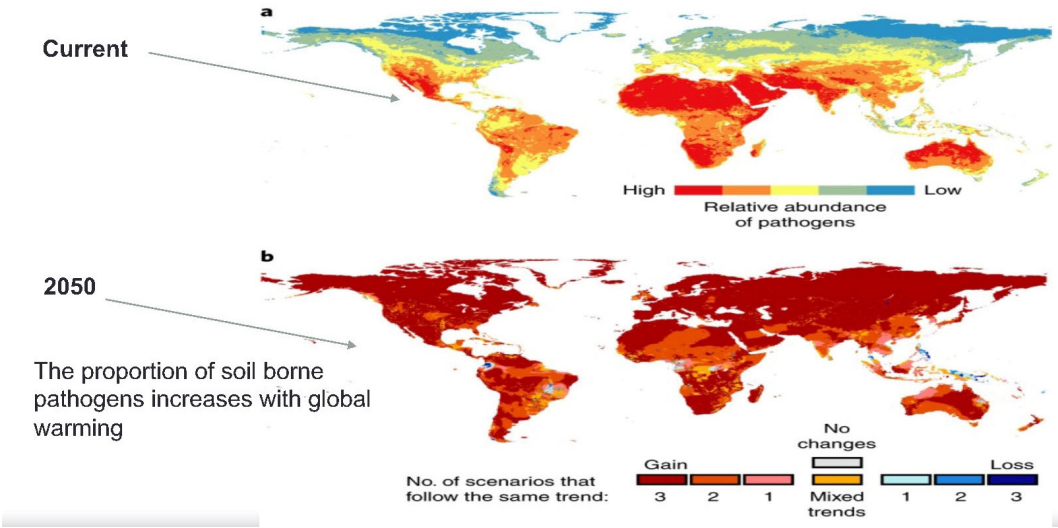


Figure 6. Current relative abundance and temporal projections (to 2050) of potential plant pathogens across the globe. *Source:* Delgado-Bacuerizo *et al.* 2020.

Climate change

Climate change and transboundary pests and diseases are very closely related. As temperatures and amounts of precipitation rise, and areas become warmer and more humid, then the incidence of pest infestation also rises. Temperate zones that did not have certain pests are starting to see pests from lower latitudes, for example. Since about 1960, crop pests and diseases have been moving north and south at an average of three kilometres a year, from tropical zones to temperate zones. Even as we talk about temperate zones benefiting from climate change, we must be clear that the negative effects of more plant and animal pests and diseases and the associated risks will also be an important factor (Figure 6). That is, the net benefits from climate change for the more temperate zones may not be as great as some people are thinking. To quote from CIMMT, 'An increase in temperature and precipitation levels favors the growth and distribution of most pest species by providing a warm and humid environment and providing necessary moisture for their growth.'

COVID-19

Consider COVID-19 – which is one type of biosecurity issue – and global food systems (Figure 7). COVID-19 provides a good example of the rapid spread and the massive impact of zoonotic diseases. Whether one considers COVID-19 zoonotic (as classified by the WHO) or not, the human health impact is very clear: it has been disastrous across the world, and one would anticipate that similar zoonotic diseases may have similar effects in the future, especially in this globally interconnected world.

However, the disease has had interesting impacts on food systems. Food systems have been found to be much more resilient than we thought they would be. Despite short-term shocks to labour and the supply chain disruptions, food systems have bounced back. Staple grain systems particularly have been found

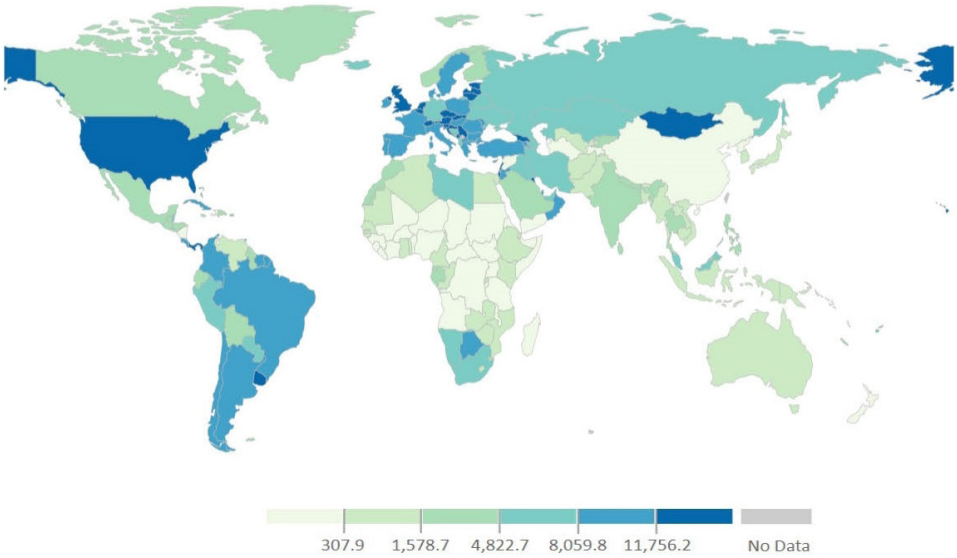


Figure 7. Global cumulative cases of COVID-19 reported per 100,000 population as at 2 December 2021. *Source:* CDC (Centers for Disease Control and Prevention, cdc.gov).

significantly resilient through the crisis. In developing countries, perishable product supply chains have been more affected than staple grain systems, through disruptions in labour, especially in movements of migrant labour and recent disruptions in supply chain labour. Also, although there has been severe food insecurity especially among poorer populations, it has been clearly a problem of diminished access because of income loss, especially for migrant labour, rather than of supply and availability of food.

A valuable observation we can take away from COVID-19 is that resilience has less to do with the production system *per se*, and more to do with labour imports and connections in the value chain. There are some important lessons there in relation to how to create safety nets during these crisis situations.

Building resilience in food systems

How do we build resilience in food systems, and protect them from biosecurity risks? (Figure 8)

When people think about biosecurity, much of their attention is on control, and on preventing biosecurity risks entering a country. I think that more attention needs to be given to addressing the problem at its source – to **preventing the incidence of biosecurity risks**.

In most cases, the problem starts with smallholder agricultural systems in developing countries, either crop farmers or animal farmers – always on small farms. We need to find ways of reducing biosecurity risks on these farms in developing countries, and by doing that we should reduce the prospect of those biosecurity impacts in other parts of the world.

Developing Country Small Farm Agricultural Systems

- Promote Diversified and mixed farming systems in place of large-scale monocultures
- "Good Agricultural Practices" (GAP) for horticulture and livestock products
- Create scale by aggregating produce through farmer producer organizations
- Climate resilient food systems that resist novel pest infestations

Value Chain Investments

- Rural Market infrastructure, including water & sanitation
- Temperature controlled transport & storage systems
- Investing in supply chain traceability

Societal Investments

- Research and Technology development for managing biosecurity risks (eg. Pest resistant varieties)
- Systems for biosecurity information exchange. (E.g. Locust watch dashboard by FAO)
- Better data systems including AI and machine learning to monitor pests and diseases
- Incorporate One Health Approach in Policy Making
- Public health infrastructure investments, including access to health services for the poor
- Behavior change at the individual and community level that promotes safe food systems

Figure 8. Building resilience against biosecurity risks.
Prevention vs control.

I think one path is to promote **more diversified and mixed farming systems**, in place of the large-scale monoculture systems that we see across the developing world, particularly with respect to staple grains. I see the importance of bringing in **good agricultural practices (GAP)** as promoted by FAO for horticulture products and for livestock products, which should improve their safety and reduce the risk of pest infestations being imported.

To connect small-scale agriculture and its produce to the value chain, safely, requires quality standards, safety standards, testing requirements, etcetera, and those, for small farms, take enormous amounts of time and create large transaction costs. How can we create a way of aggregating the produce of small farms, which will **create scale and economies of scale** in the processes of testing, and in bringing much safer products into the value chain?

I think that is an area that needs a great deal more attention.

In relation to the impacts of climate change, I think it is important for us to think about ways in which we can make **a more climate-resilient food system** that can resist normal pest infestations, such as by using varieties that are resistant to pests and diseases.

At the next level of investment are value chain investments, and for mainly rural systems those are investments in **rural market infrastructure including water and sanitation**, and in **temperature-controlled transport and storage systems, and in supply chain traceability**. I think this will be a challenge in smallholder systems, but that if there can be aggregation of produce to farmer producer organisations then traceability also becomes possible, and at much lower cost, especially with some of the new tools available today for tracing the source of different food that comes into the value chain.

In relation to society-level investments, country-level investments, or even more globally, I think **R&D is absolutely crucial for managing biosecurity risks**. Finding pest-resistant varieties offers opportunities for R&D, both for improved technologies for varieties and weeds, and also for improving value chains and processing that lead to much safer products. That is a big area.

Information exchange and early warning systems are extremely important. For example, FAO has created a locust watch dashboard. Such information platforms are very important, but by themselves do not solve the information problem unless there are good data to go onto the dashboard.

It is absolutely crucial that there be investments in **better data systems** on pests and diseases, and on our ability to track the movement of pests and diseases. The new Artificial Intelligence tools and machine learning tools may make that much easier than were past attempts at building such data systems.

From a policy point of view, I think it is vital to think about **a One Health approach** – one that looks at animal health, plant health, environmental health and human health all together – and to look at ways in which that integrated health system promotes safety across all these components and reduces biosafety risks in the future. Public health infrastructure, as we are learning from experience during COVID, is not at the level that it ought to be, especially in developing countries.

Public health infrastructure, even in relation to basics such as water and sanitation, is essential. Also essential is access to health services, especially for the poor; such services are currently extremely limited. Making those investments should help reduce the risks associated with zoonotic diseases and other diseases, especially as they affect rural communities, poor communities, and others.

Finally, I think **behaviour change** is also very important: behaviour change from the producer side in terms of understanding what is good agricultural practice; behaviour change across the value chain in identifying the points of contamination, identifying ways of ensuring safe transit of these products; and behaviour change at the consumer level in demanding better quality products, safer products, and investments in safety, making sure that as consumers we are part of this process of building a biosafe food system.

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Q&A

Chair: Professor Wendy Umberger, ACIAR

Panel: Professor Prabhu Pingali

Q: Robyn Alders, Australian National University, and merino sheep farmer

Thank you very much, Professor Prabhu, for an excellent presentation. So much of what you said links to good policy, particularly around prevention. I'm wondering what your advice would be to countries that don't yet have a national food policy? What elements do you think are key, and how do you achieve inclusive policymaking using the One Health approach that you mentioned, inter-sectoral policy? And here I simply mention that Australia doesn't yet have a national food policy either. Thank you.

A: Prabhu Pingali

Thank you so much for that question. You know, one of the issues regarding food policy in many developing countries is that food policy is seen as the same as food security policy, and because of that much of the attention around food policy is on growth of staple grain productivity, continuing the type of policies of the Green Revolution for productivity improvement. That has led to conflict between agricultural productivity and the negative effects on environmental health, human health, transboundary pest problems, etcetera.

I think it is absolutely crucial to bring the One Health concept and food policy together. If we did that, we wouldn't be thinking about food security primarily from a staple grains aspect; we'd be looking at a much more diverse food system, and we'd be bringing in food safety issues as an integral part of the food policy discussion.

Right now these are all separate discussions, and sometimes in separate ministries. And thinking about it as One Health brings that coordination together. I'm afraid I don't have many good examples of that working yet, but I think that's the future that we need to go towards.

Chair: And hopefully as Australians we can take some leadership in that.

Q: Colin Chartres, The Crawford Fund

Thank you, Prabhu, that was a fantastic talk. Your talk led me to reflect that biosecurity issues are one of many externalities that come from our food production system: the climate change situations, land degradation, and so on. And that we are still, in the West at least, consuming food which is incredibly cheap, and we're not putting aside enough funding to cover those externalities.

You spoke of the importance of prevention in smallholder agriculture where there is very little money, and I thought of the parallel in the COVID vaccination situation. In the West we're having our third – our booster – injections, but some people in the developing world have not had their first injection yet. It's another case of the same thing, where we can control biosecurity at our borders, but

This record has been prepared from a transcript.

we're not doing enough to help other countries prevent diseases and the spread of new diseases to other countries.

So my question is: what models are available in relation to funding not only disease prevention in the smallholder systems, but also the increased knowledge that's required for all consumers in developing and developed countries? And could we consider perhaps having a very small levy at the point of consumption, rather than at the point of production, in our food systems, particularly in Western countries?

A: Prabhu Pingali

I think one of the big limiting factors today is that there's not much consumer awareness of the enormous negative externalities in the current food system. We don't have good enough information on the true costs of the production systems, where you cost out all the externalities involved. The Rockefeller Foundation recently released a report on the true cost of food production in the United States, and it showed that while the monetary cost is around one trillion, the true cost is around three trillion – three times as much, because of the environmental costs and the health costs, etcetera.

That kind of number becomes a really powerful advocacy tool for the policy community, but also broadly for the more educated public to understand why the current system is unsustainable and what can be done about it, and that's where behaviour change comes into play. But I don't think we spend enough time thinking through those issues and trying to quantify those true costs. We've been talking about externalities for decades, but we've never really translated that into policymaking. And so that's one way I would recommend moving forward.

Chair: Excellent. And who did that report, Prabhu?

A: Prabhu Pingali

The Rockefeller Foundation, just a few months ago. I think it came out last July or August. It's called the *True Cost of Food*. So if you just Google 'true cost of food United States', you'll get to that Rockefeller Foundation report. I'd strongly recommend taking a look at that. If it's replicated in several countries it will create that pool of knowledge that we can use for advocacy.

Q: John Fazakerley, The University of Melbourne

I really enjoyed your talk, thank you very much, and agree with so much of it. I want to pick up on the One Health issue, with a rather specific question that you didn't stray into. I'm well aware of diseases that come out of the human transgression into the ecosystem; for example, we go into forests and we get things like chikungunya, or like yellow fever – all the diseases that come out of interfering with ecosystems – and there are a lot of these human zoonoses. Have there been studies on the diseases that come out of natural ecosystems and affect agriculture or horticulture? As we clear the forests, as we clear the lands, are we seeing diseases that come out and affect agriculture, and what is the economic cost of that?

A: Prabhu Pingali

Historically there has been work on things like trypanosomiasis and other vector-borne diseases that have come out because of expansion in irrigation systems, etcetera. But I'm not aware of enough economic assessments of the cost of those diseases and how degradation of these natural ecosystems then creates these vector-borne diseases, and how that affects human health. It's an important area, but I don't think there's been much work on that for several decades now.

Q: David Shearer, Commission on Sustainable Agriculture Intensification (CoSAI)

You were here in 2008 I think, during the phase of globalisation, and at that stage there was some question about the role of the smallholder in our transformed food system. But in the period we're in now, it appears the smallholder farmer will always be a central component of our future food systems. Also, at the time of the Green Revolution, the key factor there was access to innovation. It was a little bit siloed because it was just technology, supported primarily by public extension.

Now I want us to think about the future, and I'm going to promote some work I'm doing, at the moment, for the Commission for Sustainable Ag Intensification. You can Google it and you'll find this research.

We assessed the level of investment in innovation in smallholder systems, and so we determined that there's about $60 billion of investment going into smallholder innovation. But now thinking about your future, which is about environment and social matters, what that study determined was that between 2010 and 2019 only 7% of that innovation investment explicitly called out environmental impact, and less than half of that investment explicitly called out the social objectives that we want to meet: nutrition, livelihood improvement, etcetera. And we also know the important nature between public and private investment to drive innovation.

My question is: how do we drive investment globally that enables smallholders to access innovation, technology, policy, finance, institutional capacity, that allows us to tackle those future issues, so we no longer have 7% of innovation investment going into environment, but we have a much more balanced portfolio for the future of our food system?

A: Prabhu Pingali

There's one way to think about it, and that is as urban populations become more aware of the food that they consume, there's an increased demand for safer food, for better quality food, for better diversity of the food basket, etcetera. That's on the demand side. And on the supply side, much of the food production, and especially in developing countries, will continue to be smallholder production systems that then feed into this urban demand. The process of smallholders connecting into these value chains has always been very complex and complicated. If there are ways in which private sector investment can promote better quality food, safer food, more environmentally sustainable food, then private sector investments in value chains that bring in these types

of foods into urban markets is, I think, probably the best way in which one can influence future food production systems.

That would not only help improve the sustainability at the farm level, and ensure better quality food for urban consumers, but it also becomes a real growth opportunity, and income growth opportunity for small farms, and this will give an opportunity to get beyond staple grains. That means the extension system moving from public extension to more private-sector oriented extension systems. That's the way I would think about it. But, you know, these are all scenarios. We have to see how things evolve over time, and what incentives there are for private sector investments and for small farms to change the way they behave here.

Q: Howard Parry-Husbands, Pollinate and Metamorphosis

I was intrigued by the point you made about the limiting factor being not much consumer awareness of the true cost of production systems. Is there enough collaboration beyond agricultural and food expertise with sociologists, with marketing professionals, with communications experts, to address this significant limiting factor?

A: Prabhu Pingali

I think that right now much of the discussion is very siloed among the different groups, and the agricultural production community doesn't really spend enough time communicating with the consumer groups, etcetera, and the environmental community doesn't really communicate enough with the agricultural production side, the research side or the consumer side. I think one of the issues for the nexus is to create that communication bridge, and to break up those silos. And that can only happen, I think, from the demand side. It can only happen as consumers become more aware and we start to demand higher quality, safer food, more sustainably produced food, etcetera. But we're still a very long way away. It's still a big challenge even in countries like the US. It's going to be a long time before countries like India get onto that same wavelength.

Chair: Thank you all.

Reference

The Rockefeller Foundation (2021) *True cost of food: Measuring what matters to transform the U.S. food system*. July 2021. https://www.rockefellerfoundation.org/report/true-cost-of-food-measuring-what-matters-to-transform-the-u-s-food-system/