Helping farmers innovate to harvest more from less

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Abstract

By 2050, we face the challenge of feeding 50% more people within the finite and diminishing resources on the planet. Significant investment is going into the development of new crop varieties that will offer higher yields, greater pest resistance or better tolerance of adverse conditions. There is also a vigorous debate about the potential to extend available farmland and increase the global area under cultivation. These developments can be only part of the solution. Agriculture will face increasing competition for scarce water and land resources as society seeks to balance its needs and desires for more food with demands for increasingly scarce (and hence lucrative) mineral resources, space for urbanisation, protection of ecosystems and protection of biodiversity. Simply expanding agricultural capacity will not be sufficient. We must lose less of what we already grow and use existing inputs more efficiently if we are to meet the challenge of achieving global food security. On average, 40% of the crops grown worldwide are lost to pests and diseases before they reach the consumer, on top of which is wastage during processing, spoilage at retailers and over-purchasing by consumers. This paper considers how innovations in pest management, water usage, fertiliser technology and soil health improvement can help us feed more people. To be effective, new technologies or techniques must be communicated to and adopted by farming communities around the world for innovation and uptake to take place. In the face of a chronic shortage of funding, skills and resources to support extension systems worldwide, this paper also looks at how new approaches and technologies can be used to get relevant actionable information to rural smallholders.

The problem

The challenges of feeding a growing world population have been well documented in many press articles and position papers. To feed a global population projected to grow from 7 billion now to 9 billion by 2050, the world's agricultural productivity must increase in the next 40 years by as much as it has in the previous 12,000 years. That growth must be achieved in the face of a perfect storm of other factors such as rising energy prices, dwindling mineral resources, shortage of water and, of course, climate change.

Simply increasing the area of land we cultivate is no longer an easy option, with growing demands to use land for housing (urban and rural), mining, water storage, recreation or the preservation of biodiversity. Paradoxically,

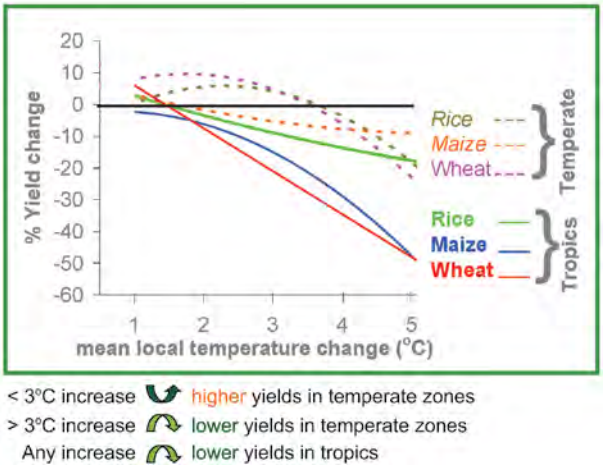

Figure 1. With higher temperatures yields are generally expected to be lower. (Adapted by Norgrove from IPCC (2007) based on 69 studies.)

as development initiatives succeed and living conditions improve, the task gets harder. Increasing incomes around the world increase the demand for meat and dairy products, requiring larger inputs of fodder and water per calorie or kilogram of nutrient produced, as well as increasing the overall greenhouse gas emissions from farming.

The debate today is often focused on cereal crops — rice, maize, wheat. These are vitally important in terms of food security and they are naturally the focus of a lot of our breeding efforts. However, we also need to think about vegetables, about fruit, and about cash crops such as cocoa and coffee that provide essential dietary nutrients and variety or valuable income for smallholder households, particularly in the tropics.

Nor are we operating on a level 'playing field'. Many of the cereal crops that are grown today have been optimised for the temperatures and climatic conditions of 10 or 20 years ago. If temperatures actually rise by the amounts predicted by some of the climate change models, then many of the varieties in use today will no longer be growing within their optimum temperature ranges. Yields from current cultivars of rice, wheat and maize could decline significantly, particularly in the tropics (Figure 1).

New varieties are critical in helping meet those challenges, and the potential for developing traits with resilience in a harsher climate is now much greater as a result of advances in both conventional and biotech breeding approaches. Therefore, despite an apparently gloomy prognosis, I remain optimistic that we can find and, more importantly, implement new ways of working to address these challenges.

This paper reviews some of the potential solutions offered by technology and then considers new opportunities that modern communication technologies provide for creating awareness and uptake among smallholder farmers. It considers some of the broader mechanisms that must be put in place to really enable and drive that change. The focus is on helping make farming a profitable and attractive rural profession, not just a last resort for scratching out a living.

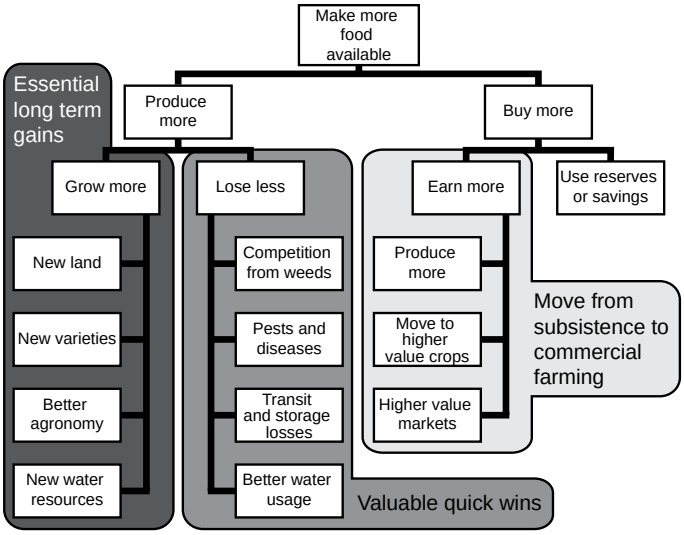

Figure 2. Food security can come through building or buying.

Will technology help us find the solutions?

In looking to achieve food security at household, community or national level we can seek to either produce more food or to buy more.

In relation to producing more, there are two sides to the equation: to grow more, and to lose less (Figure 2). By helping farmers earn more we can also enable them to buy a better variety of diet and make them more resilient to price and supply shocks. The focus of most research and technology development effort is to find ways to grow more, and this will be essential to meet the challenge. Unfortunately, the time period for introduction of a new variety is typically 10–15 years so that these gains will be in the longer term.

However, we can gain some valuable quick wins by focusing effort on the 'lose less' side of the equation. It is a shocking fact that, on average, 40% of what is already grown is lost — to pests, weeds and diseases — yet we already have much of the knowledge needed to reduce these losses. Therefore, a focus on losing less could give us some valuable quick successes in the war on hunger.

As an example of the potential for yield improvement through knowledge and technology available today, consider the Philippines. It is both a major rice-growing country and a significant importer to meet domestic consumption needs. Current domestic production in 2010 was 15.8 Mt and this was augmented by imports of 1 Mt to meet total consumption of 16.8 Mt (Philippines Department of Agriculture). However, it is estimated that total losses because of pests, diseases and supply-chain wastage amount to 4.8 Mt per year. The International Rice Research Institute (IRRI) also estimates that adoption of the most suitable hybrid varieties could increase yields by 10%. So, in theory, by halving its losses and adopting hybrids the Philippines could increase rice output by approximately 4 Mt, giving it the potential to become a net exporter of up to 3 Mt of rice per annum.

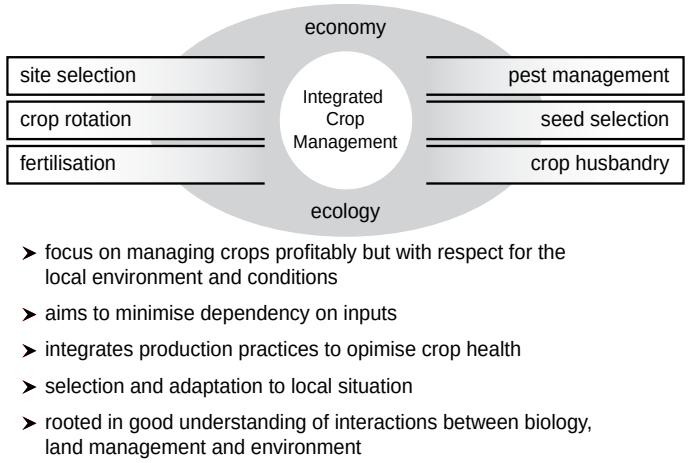

Figure 3. Integrated crop management relies on good understanding of interactions between crop biology, pest ecology, land management and the landscape.

Modern biotechnology promises potential benefits for the future, such as greater tolerance of heat and water stresses, resistance to pests, resilience to saline conditions or even the fundamental re-engineering of nutrient content, nitrogen fixation and photosynthetic efficiency in some crops. Many of these developments are not dependent upon genetic engineering and so will not get delayed by the debate over public acceptance of genetically modified organisms. Recent rapid advances in the sequencing of plant genomes, and the reduction in the cost of such techniques, now make it possible to accelerate the introduction of desirable characteristics through traditional plant breeding techniques that have been used for hundreds of years. Instead of making crosses and patiently waiting to see if the resulting plants have the desired traits when they are grown in the field, we can now identify the genes responsible for the desired traits and use molecular markers to check whether they have been brought together in the breeding process. Work by the World Vegetable Centre (AVRDC) on plants such as tomato and eggplant has already shown that many of the desired characteristics of stress tolerance, nutritional quality, flavour and appearance can be achieved through such breeding approaches.

In seeking to reduce crop losses, it is essential to take a systematic approach, not just focusing on the crop itself but also taking into account the soil conditions, environment, pests and weeds around that crop, as well as site selection, crop husbandry, storage and transport to market (Figure 3). Integrated crop management practices must be rooted in a good understanding of interactions between crop biology, pest ecology, land management and the broader landscape to ensure that agricultural practices are sustainable and serve as a foundation for future generations.

CABI is one of nine organisations forming the Association of Independent Research and Development Centers for Agriculture (AIRCA) which seeks to develop and promulgate support of healthy landscapes through an innovative

systematic approach to agricultural development. The approach balances the imperative to lift yields and outputs against the need to secure the sustainability of the environment within which that production takes place. AIRCA will address the challenge of increasing global food security by identifying and disseminating science-based development solutions to problems met in smallholder agriculture within the context of healthy, sustainable and climate-smart landscapes.

In much of Africa and Asia there are large gaps between actual and optimum yields for most crops. In closing these gaps, we need to value and use water as a precious resource. Agriculture is the biggest, and probably most wasteful, user of water worldwide; it is imperative to get more crop per drop. With basic good practice and simple technology it is already possible to achieve usage savings of anywhere from 15% up to as much as 50%. At its simplest, this just requires better management of available resources through fixing leaks, improving drainage and irrigation systems, storing available rainfall and using greywater where appropriate. Techniques of mulching or alternate wetting and drying (for rice) significantly reduce evaporative losses and water usage whilst the adoption of drought tolerant varieties can make the farming system more resilient to water shortages. For a relatively low capital outlay (perhaps supported through development grants or micro-finance) farmers can invest in drip irrigation systems to use water more efficiently and reduce the problems of salinisation that can arise from over-watering. In more commercial farming environments water accounting and pricing systems can give farmers an incentive to minimise water usage, and telemetry and precision agriculture techniques can help them apply just the right amount of water, in the right place at the right time.

Soil health is also a major problem in much of Africa and South Asia, where practices designed to maximise output have mined the soil of available nutrients, created saline environments or degraded soil structure, leaving it prone to erosion. The benefits of low-till or zero-till strategies have been known for many years. Even though they have been widely demonstrated, uptake is still not widespread. Good agricultural practices of crop spacing, timing of planting, weed and pest management, as well as crop rotation are also relatively simple for farmers to implement once they have the necessary information (Figure 4). It is critical that this advice is carefully adapted to local conditions and crops for it to have impact.

These practices can also encourage farmers to use organic fertiliser inputs from manure, compost or legumes, because access to mineral fertilisers of good quality, at reasonable prices and in appropriate quantities is often a problem, particularly for smallholder farmers in Africa. In contrast, in some parts of Asia there is often over-usage of mineral fertilisers, leading to unnecessary costs for farmers, as well as unwanted run-off into streams and rivers. Organisations such as the International Fertilizer Development Center are encouraging advances in micro-dosing and formulation, as well as simple decision tools and guidelines, to help smallholder farmers use inorganic fertilisers more effectively and efficiently.

Losses to pests, weeds and diseases are major problems to farmers worldwide. Furthermore, climate change, trade flows, travel and population movements are

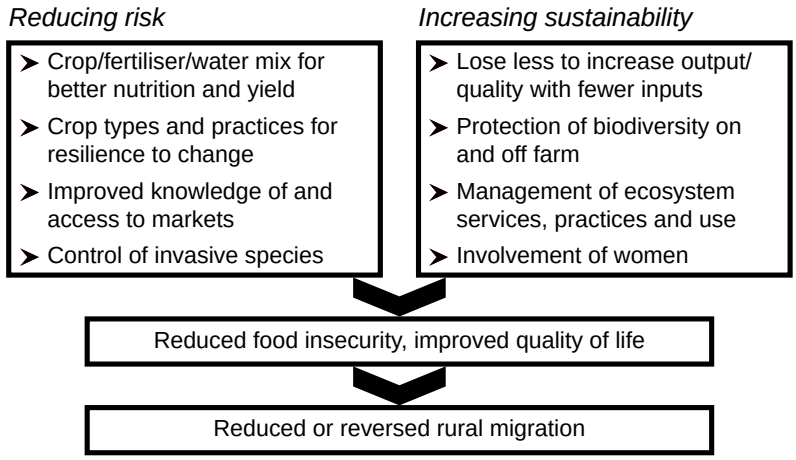

Figure 4. Healthy landscapes help make rural communities more viable.

increasing the rate at which new problems arise and spread. The importance and nature of these acute problems vary between smallholder and production systems, and from year to year as well as within and between countries. Crop protection projects address a limited range of major plant health problems on a limited range of crops, yet livelihoods depend on complex agricultural systems, with a variety of crops and livestock. Often, farmers do not have easy access to diagnostic services to help them identify the problem they are seeing or to give appropriate advice on how to manage that problem. This can lead to farmers relying on advice from friends or input suppliers, which can result in application of inappropriate and expensive chemical treatments. In many cases, problems can be more effectively and sustainably dealt with through integrated pest management approaches to crop production and protection. Those approaches combine a range of management strategies and practices, particularly the use of cultural, biological and mechanical methods to grow healthy crops and minimise the use of pesticides.

How do we get technology adopted more effectively?

Many smallholder farmers in Asia and Africa generally have mixed cropping systems, spreading their risks, but broadening the range of knowledge and advice they need to grow each crop successfully. The advice has to be reliable: available when needed, accurate, appropriate and proportionate. Sources of potential advice include public and private extension providers, agricultural institutes and local agro-dealers. Information is more widely available than ever before, and yet advisory services are weak, with a fundamentally poor dialogue between farmers and those who aim to help them.

As described in the preceding section, many of the technologies we need to close yield gaps and reduce inputs of water, energy and chemicals are already developed and available. Despite this, many farmers in the developing world are not aware of these techniques or have not adopted them. If the food security

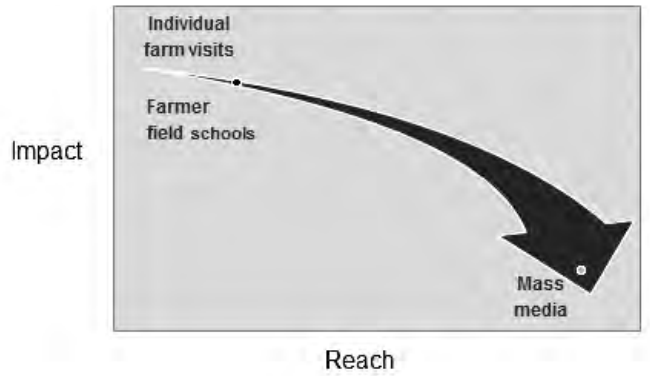

Figure 5. Farm visits can only reach a few farmers, and field schools also reach relatively few, but the farmers learn well; mass media reaches many farmers but teaches little.

challenges of the next 50 years are to be met, our highest priority has to be to improve resources, systems and methods of extension around the world in order to make better use of what we already know.

An inconsistent engagement with farmers also has several important longer-term consequences: slow awareness of new and emerging plant health problems; delayed responses in identifying the nature of the problems and giving suitable recommendations; systematic failure to learn from experiences; and inefficient use of existing sources of technical expertise. The net result is a failure to provide timely solutions that enable farmers to grow more food and earn more money.

Until recently, extension in the developing world either took the form of a face-to-face farm visit by an extension worker or relied on the use of mass media channels such as advertising in newspapers. The former has high impact but limited reach because the number of extension workers is small and farms may be far apart. Conversely, newspaper or radio campaigns can reach a large number of people but tend to be non-specific and have low impact (Figure 5).

Farmer field schools were developed as one way of reaching more farmers, but the approach and choice of crop or topic remains top-down and often does not address the most pressing problem faced by each individual farmer. Providing regular and reliable demand-driven advisory services requires innovative solutions that recognise the entrenched weaknesses in agricultural support systems, namely:

- there are not enough extension workers to reach all farmers;
- technical expertise is limited and difficult to access;
- the availability of inputs depends on supply chains that are erratic and dominated by agro-dealers.

There are also positives to build on, though these are often ignored:

- extension workers have a good knowledge of farmers and local conditions;

- technical experts want to work more closely with extension;
- agro-dealers want to respond to customers' needs and to be trusted.

CABI and others have been looking at ways to increase the reach of extension services whilst still maintaining the impact of their messages.

In Bangladesh, CABI has used community videos, made by the women of the villages themselves, to spread the word about best practices and new techniques for identifying quality seed, drying it and storing it for future harvests. As a result of the local relevance and credibility of these videos the awareness of proper seed management increased from 41% to 94% in the communities involved.

In Africa, with funding from the Bill and Melinda Gates Foundation, CABI has set up the African Soil Health Consortium as a communication mechanism to transfer knowledge on best practice in soil health to extension workers, agro-dealers and farmers.

In India, in a partnership with the leading mobile network operator (Airtel) and a major fertiliser supplier (IFFCO), CABI has supported a mobile agro-advisory network that now serves 4 million subscribing farmers. They receive up to five voicemail messages per day on a variety of relevant topics including weather, market information, pest alerts and crop management advice.

Plantwise

'Plantwise' is a major initiative, led by CABI with financial support from donors in the UK (DFID), Switzerland (SDC) and Australia (ACIAR), to bring better knowledge and advice to farmers for the identification and management of pests and diseases so as to reduce the losses and improve the quality of their crops. Plantwise is disseminating and gathering knowledge in two ways:

- locally, via a network of plant clinics in the developing world to help the poorest farmers, diagnosing plant health problems and giving them a 'prescription' for the problem; and
- globally, via a knowledge bank of data and information which supports the clinics but also aggregates and analyses their observations.

Plantwise clinics are set up at local meeting places, such as markets, village halls or agro-dealers, where farmers congregate in the normal course of their business. They provide a service that is either free at the point of use or has a small nominal charge. The clinics are run by local extension staff employed by the relevant national agencies so they use existing resources but enable extension workers to have high impact personal interactions with many more farmers. Plantwise has already trained over 1000 plant doctors who are now running 354 plant clinics in 24 countries. By 2016 CABI is aiming to expand coverage to over 40 countries and 1000 clinics.

For long-term sustainability, plant clinics need to be embedded in national systems and organisations of plant health, encompassing regulatory bodies, national plant protection organisations, advisory services, universities and agricultural research institutes. The Plantwise initiative also provides an innovative way to stimulate the partnerships needed to strengthen national plant health systems and to help them identify and manage plant health problems,

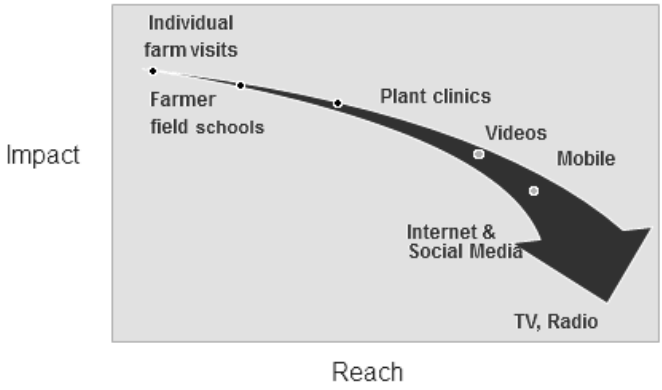

Figure 6. Modern communication technologies offer many ways of helping farmers learn.

including biotic and abiotic constraints. Plant clinics have many strategic advantages: they respond to and monitor shifting demands of farmers from year to year, by place and by production system. Yet plant clinics alone cannot solve all the problems that farmers face.

Plantwise has a knowledge bank that supports plant clinics and plant health systems by providing a platform for information sharing at national, regional and global levels. It provides open access to a wide range of information — from international scientific literature to simple actionable fact sheets in local language for use by extension staff and farmers. The database provides material that will be relevant at the level of the plant doctor or extension worker to enable them to help a farmer on the ground. At the same time it aggregates regional and global perspectives on the spread of plant health problems.

By collating feedback and observations from the network of plant clinics, Plantwise creates a unique source of information on what is being seen at the local level. At critical mass of clinics, these data, together with analysis informed by scientific knowledge, will provide a powerful global early warning system for plant health vigilance. Countries and regions can be alerted to potential threats and able to prepare improved local responses to problems and climate change.

These examples show the potential of today's information and communication technologies to make existing knowledge more widely available. This can give extension and advisory services new opportunities to use their limited resources to communicate with farmers in ways that have greater reach, frequency and impact (Figure 6).

Supporting farmers to make change

To enable change to take place, conditions need to favour economic as well as biological sustainability. A sustainable farming community is one in which the farmers make a living that motivates them to stay and farm rather than seeking higher income in the cities. There is now widespread agreement that improving smallholder productivity is essential for increasing food supply, but there must

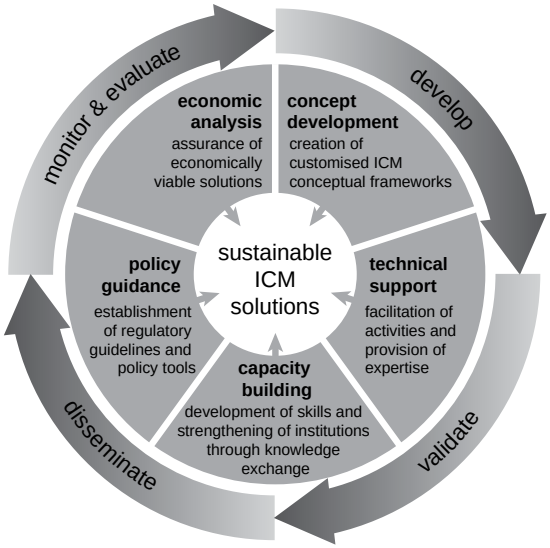

Figure 7. CABI aims to establish a virtuous circle of actions, support and guidance, to help smallholders achieve sustainable integrated crop management (ICM).

also be a vision of how to help smallholders make a business out of their farming (such as is indicated in Figure 7). For farming to become a profitable and respected rural profession farmers need to be able to connect to markets and get a fairer share of the value they create when they improve the yields of their crops. For example, in Tanzania, CABI has helped tomato growers adopt integrated pest management techniques to reduce pesticide residues on the produce. It has helped the growers establish producer clubs and develop branding for their produce so as to sell into higher value urban markets.

In the implementation of innovation, partnerships with the private sector will be an important enabler. At the most basic level, new seeds, inputs or technology must be available to farmers through local agro-dealers at reasonable prices and in appropriate quantities. Farmers also need access to financial products in the right package sizes.

For example, in recent work funded by the Common Fund for Commodities (CFC), CABI helped coffee farmers in Rwanda and Ethiopia produce higher quality coffee by introducing more effective methods of drying the coffee cherries. Farmer field schools were used to teach farmers the new processing techniques and producer clubs enabled them to achieve 30% price premiums for the better product that resulted. However, many of the farmers could not afford the capital outlay required to buy the simple equipment needed to improve the drying process. Therefore, in a second phase of the project, again supported by CFC, CABI partnered with Rabobank of the Netherlands to establish lines of microfinance credit to enable farmer groups to purchase the driers.

Farmers also need help to manage uncertainty. Agriculture involves making everyday decisions in response to unpredictable conditions and unknown

risks. The poorer the farmer, the greater the risk and impact of making a wrong decision or failing to get advice on time. Even with good advice, the initial cash outlay and financial risk of new approaches may seem too much for a poor farmer whose family depends on the income from the farm. Farmers are naturally cautious and, as a result they often stick with tried and trusted varieties or approaches. Novel micro-insurance initiatives, such as Kilimo Salama pioneered by the Syngenta Foundation, help reduce the risks by selling insurance against adverse weather effects (such as drought or flood) along with the seeds. Mobile phone technologies are stimulating innovation by making these novel offerings of micro-credit and crop micro-insurance possible through reducing the acquisition and transaction costs, as well as offering novel methods of payments (m-PESA, for instance: 'mobile-money' in Swahili).

In summary, meeting the challenge of feeding a growing world population will require farmers to innovate so as to produce more from less. This is not just about funding agricultural research focused on growing more, but also about building capacity and spreading existing knowledge to help us lose less.

If we are to succeed in this endeavour we must develop better methods of disseminating technology, assess and validate the outcomes to learn what works, and integrate this within a framework of supportive economic and environmental policies.

There must be balance between the imperative to lift yields and outputs and at the same time secure the sustainability of the environment within which that production takes place.

To quote Gro Harlem Brundtland, former Prime Minister of Norway and Director General of the World Health Organization:

> *You cannot tackle hunger, disease and poverty unless you can also provide people with a healthy ecosystem in which their economies can grow.*

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Under Dr Trevor Nicholls' leadership, CABI has developed a strategic focus on providing knowledge to enable poor rural farmers in the developing world to grow more, raise quality and increase income. Previously, his career covered experience of building international businesses in the genomics and life science industries serving major pharmaceutical, biotech and academic clients. He has broad experience of initiating change and restructuring organisations, ranging from start-ups to FTSE 100/Nasdaq quoted companies. Trevor holds a BA and D.Phil in Biochemistry from the University of York and Diploma qualifications in Marketing (CIM) and Company Directorship (IoD).

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