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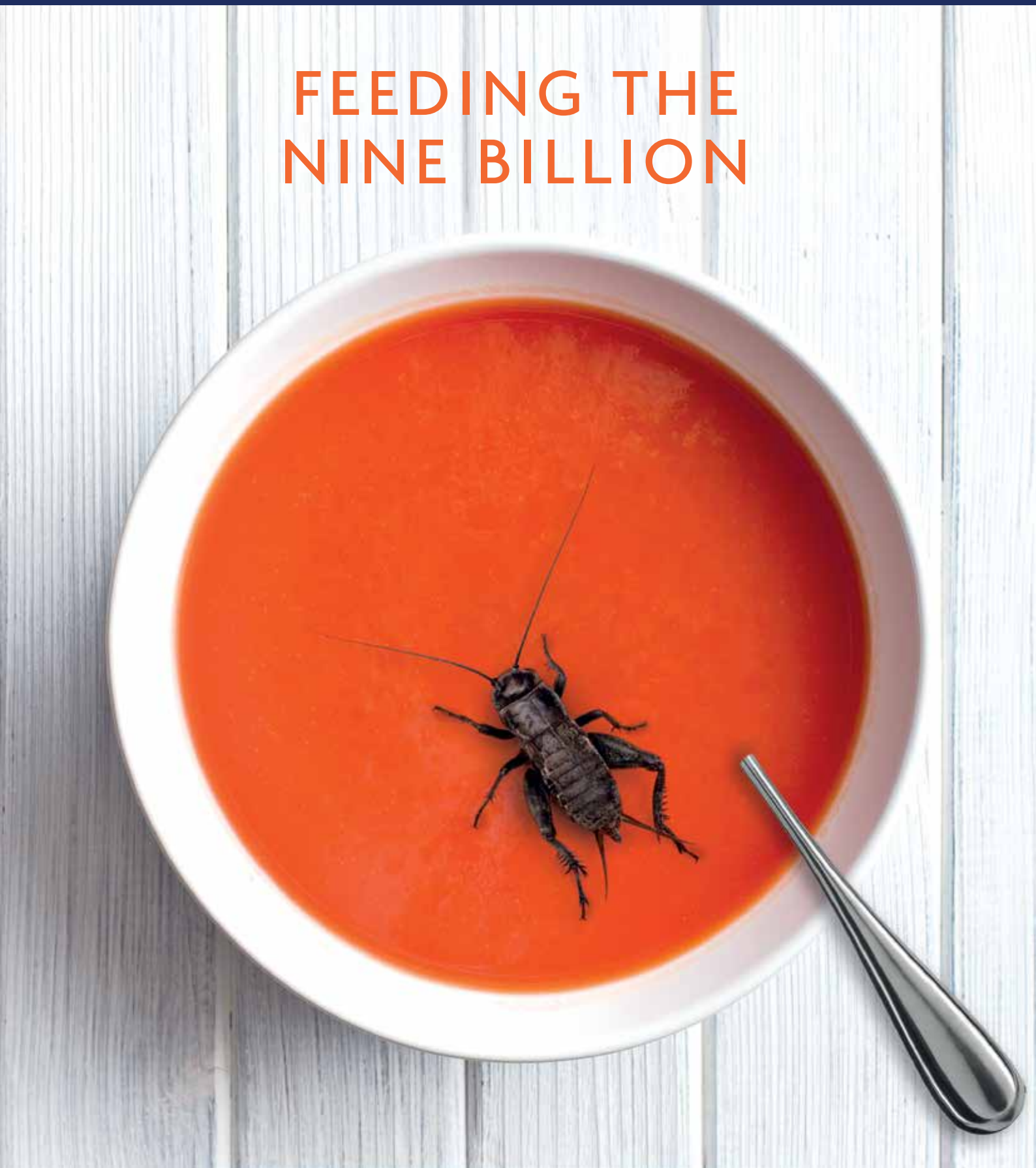
# FEEDING THE NINE BILLION



# Smart cities need smart farms

**Dr Stephen Hallett** describes how the relationship between Cranfield University, industry and the farming community is helping to work towards sustainable food production to meet increasing urban demand.

Take a look at your average shopping trolley and it's likely that more than half of the food within will have been imported. As a country with a rising population, our demands for food outpace our ability to grow it. Internationally, the latest estimates suggest the world's population is likely to hit nine billion by 2050. Added to this, the UN estimates that some 54 per cent of the world's population now live in urban areas, with a predicted increase to 66 per cent by 2050, and for this population in particular, there are fewer opportunities to become self-sufficient for food. With this, we will see further draining of our natural resources and increasing tensions around them, together with rising numbers of people abandoning the countryside and moving to the cities for work, as well as diets worsening, resulting in a myriad of health implications. Added to this mix, the effects of climate change are hard to predict and plan for. And of course here in the UK, Brexit has resulted in a falling pound, with import prices likely to increase, exacerbating the situation. Taken together, this paints an unsettling geo-political picture for future food security.

FEATURE

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It is no less comforting when one thinks about this in terms of land management, with one question standing out: how to achieve increased food production given the finite amount of land, and indeed how much land is that? It is when we consider the Earth as a whole that the scale of this challenge becomes painfully clear. Imagine for a moment that the Earth is an apple; 74 per cent of that apple is water, and of the remaining 26 per cent land, some 13 per cent is already inhabited, leaving 13 per cent for agriculture. However, of this, 10 per cent is suitable only for non-arable land, leaving just 3 per cent of usable land for arable farming. And just as an apple has a peel, so too does the world have a fragile layer – soil. This precious resource, less than 3.1 per cent of the Earth, has to support a population that took hundreds of thousands of years to reach one billion, and then only a further 200 years to reach more than seven billion. The situation appears increasingly unsustainable, especially when we may have as few as 60 harvests worth of topsoil remaining, as has been bleakly warned by the UN Food and Agriculture Organization (FAO)[1].

We must also contend with living with environmental change. The impacts of our changing climate will affect how we can use land and what crops can be grown; the UK is no different from anywhere else, and will be affected by these changes. In some cases these changes may have positive effects such as reported in a Cranfield study which noted how changing temporal soil wetting patterns can benefit autumn-sown crops[2], but in many cases it is likely to be negative as droughtiness increases.

What is needed for tomorrow, to meet the food security challenges of today, is a new approach to farming; and not just technical improvements on existing approaches. Researchers at Cranfield University are working on a number of novel initiatives to support the farming community and to help deliver the sustainable intensification that is required if we are to improve yields, reduce demand on imports, and protect the fragile environment. It is the blend of innovative scientific methods and techniques, the co-development of approaches drawing across different academic disciplines, the active collaborative engagement with industry, and the harnessing of new and promising technological development (such as big data approaches) that will drive the new agri-technological revolution.

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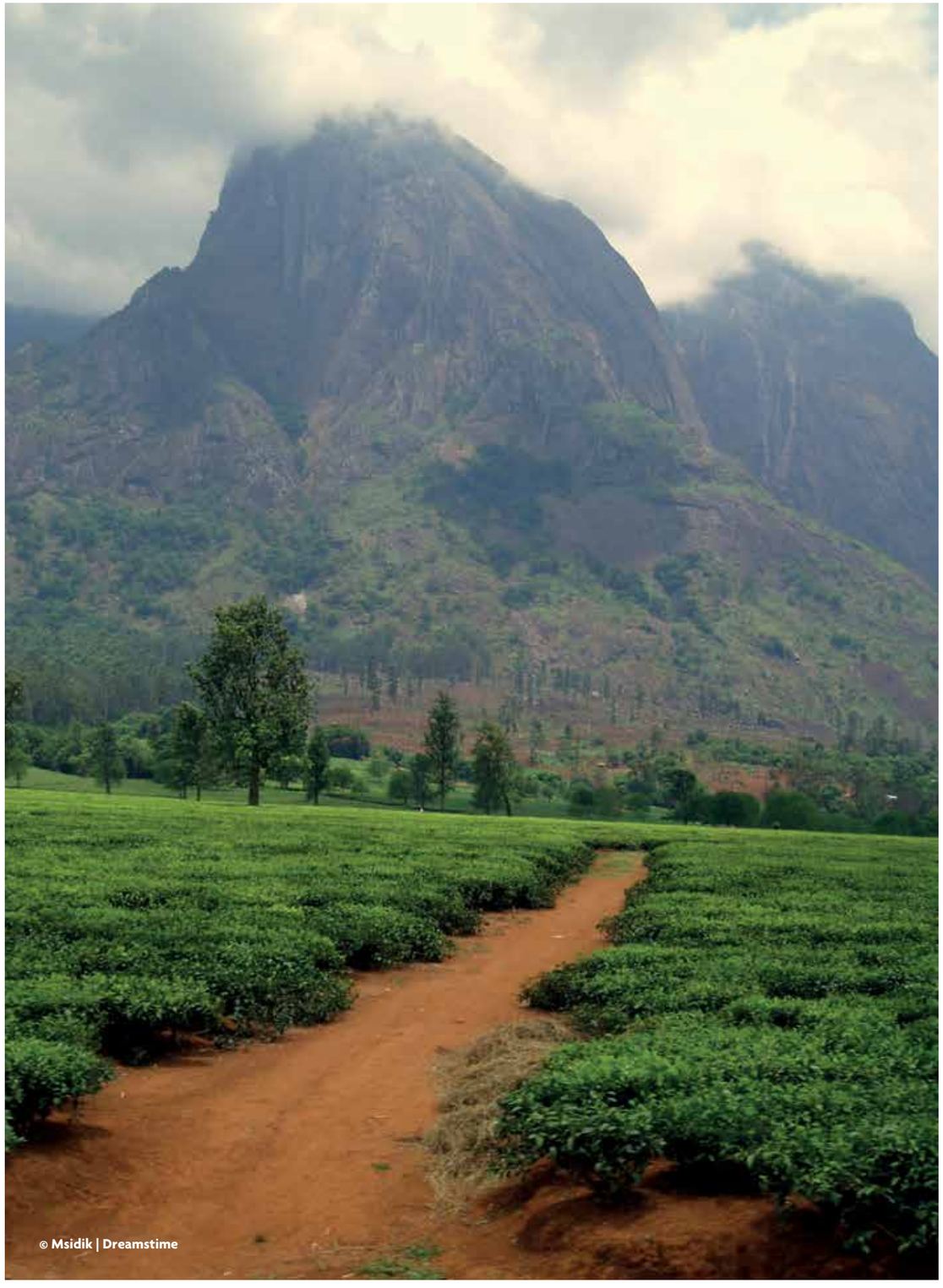
## BIG FARMING DATA AND PRECISION FARMING

Developing scientific approaches to maximise on-farm production efficiencies is essential. Cranfield scientists are fortunate in being able to draw on huge environmental data resources, having the responsibility for managing the soils data and national soil maps for England and Wales. Cranfield's National Soil Collection and Archive today contains hundreds of thousands of observations and records of soil properties and characteristics, recorded alongside the geographic location of different soil types (in the form of maps and point observations). It has been said that "What the Natural History Museum does for dinosaurs, we do for soil!" A huge task over the previous three decades has been the computerisation of these unique land and environmental records, which have been used to form LandIS, the Land Information System[3]. Cranfield University's LandIS team maintain and provide expert analysis on this resource for many groups of users of soil information, used then to inform, enrich and improve wider technical advances in remote and proximal soil observation.

Government reports have highlighted how "Eight great technologies" will propel the UK to future growth. These technologies include Big Data, Space, Robotics and Agri-Science – all of which have a direct relevance to the future farm. The adoption of 'Big Data, agri-informatic' approaches is today becoming more prevalent, in ways that were just not possible, even a few years ago. Technological advances are being implemented now in the land-based sector that have been in use in other industrial sectors for some time. One advantage of this is that lessons learned elsewhere can be taken on board. There is a wealth of information on soil and land types, meteorology, engineering, agronomic options and practices, and farm level outcomes that, when used collectively, can enhance farming efficiency, increase yield and reduce inputs to help feed our rapidly growing global population.

Drawing together existing data is only half the picture. Alongside our ability to develop novel means to collect and represent land-soil characteristics, we are also able to fuse together traditional, or legacy, datasets and present-day data sources. This includes traditional soil survey assessments and meteorological, agronomic and soil management activities, analysed alongside contemporary sources of on-farm data collected by farm machinery, in-field investigation and proximal sensing, plus advanced satellite and airborne Earth observation (planes and Unmanned Aerial Vehicles [UAVs] remote sensing investigations.)

Cranfield's work with AgSpace Agriculture Ltd. (AgSpace) is one such example – a collaborative industrial project aiming to help arable farmers and landowners from all over the UK make a more affordable entry into the world of precision farming[4]. Employing high resolution satellite data processed using a soil brightness algorithm to show where variation in soil characteristics vary 'within field', this data is being analysed and modelled alongside LandIS to produce, for the first time in the UK, a new precision soil map. This approach presents an economically viable alternative to



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the current labour-intensive method of field soil survey, with growers able to increase yields with lower input costs and reduced environmental impact.

Precision farming involves dividing farmed land into management zones where each possesses specific characteristics – soil related ones being the most important. Using such 'within field' precision data has been proven to lead to better yields across all crops, when compared with conventional 'whole field' farming. However, to date, the high costs of entry have proved a barrier for many small-scale farmers.

Another exciting project example is Cranfield's Soil for Life initiative[5], a collaboration with Produce World Group TM, one of the largest expert growers and suppliers of high quality fresh vegetables in Europe, which seeks to use big data techniques to provide a toolkit for farmers to drive continuous improvements in soil health, marketable yield and agricultural sustainability. Soil for Life aims to allow an in-depth analysis and exploration of the big data supplied by leading farmers, providing robust scientific evidence to support and underpin sustainable, profitable agriculture through improvement in soil health at the field, farm and enterprise scale.

## INTERNATIONAL COLLABORATION

Similarly to LandIS, Cranfield University also holds a unique worldwide soil and land archive, the Worldwide Soil Survey Archive and Catalogue (WOSSAC)[6]; a unique body of data and records collected over the past 60 years from over 300 territories around the world, with a strong African representation, providing a unique insight into soil resources globally.

But how do we use this wealth of information in a way that helps people on the ground, often in less developed countries than our own? One recent example of how this information can help has been its incorporation within the world's first *Soil Atlas of Africa*[7]. In this seminal European initiative, leading soil scientists from across Europe and Africa collaborated to develop this atlas using state-of-the-art computer mapping techniques to reveal the changing nature of soil across the continent, helping to explain the origin and functions of soil, and describing the different soil types that can be found and their relevance to both local and global issues. The atlas also discusses the principal threats to soil and the steps being taken to protect soil resources.

All well and good. We have WOSSAC, we have a Soil Atlas, but how does that help people on the ground and improve yields? Let's look to Malawi, where agriculture is a key activity and farmers are being challenged to produce more cash crops (tobacco, tea, coffee, etc.) against a background of increasing resource limitations, such as a lack of water, fertilisers and energy. Smallholder farmers, growing such staple crops as maize and vegetables, often cannot afford commercial mineral fertilisers. One means to address this is to use locally produced, renewable sources of soil improvement. Several Malawian farmers have been applying a specialist type of compost known as *Bokashi*, made from a mixture of charcoal/ash, maize bran, top soil, dung and water. The application of Bokashi has been shown to improve soil fertility considerably when used alone or as a supplement to other fertilisers. This is a great example of how big farming data, new technologies, and international collaboration together can bring about more food to feed more mouths.

Thinking back to the apple analogy; just 3 per cent of the Earth's surface is suitable for arable crops. Strikingly, it is estimated that the global extent of agricultural land in 2011 was approximately 49 million km$^2$, of which some 11 million km$^2$ (approximately 24 per cent) are found in Africa[7]. However, Africa only accounts for 16 per cent of the world's arable land (just over 2.2 million km$^2$). We need to work proactively with partners in Africa to shift these figures, delivering much needed food to the region and beyond.

Unfortunately, the history of large scale commercial agri-business operations in Africa is disappointing, with a history of failures that occurred primarily due to mismatching enterprises with their physical environments. These stretch back to the now infamous post-war Groundnut Scheme in the then Tanganyika, and more recently to centre pivot irrigated schemes in West Africa. However, there have been successes where large scale cultivation of new crops has flourished and has been sustainable for decades in suitable conditions, such as cotton in the Gezira of Sudan and sugar cane in the eastern Swaziland Lowveld.

If we can combine soil resources and agri-technological advances, and promote collaboration (as we are doing, by example with organisations such as AgSpace, and Produce World), we can help improve farming management methods and consequent crop yields. Lessons learnt from this can be applied beyond our borders, helping farmers around the world to better understand the soil below their feet and the crops that would best suit them.

Strong academia-industry collaborations are essential and we are fortunate at Cranfield to possess fantastic facilities to put collaborative thinking to the test. For instance, we are key partners in the Innovate UK initiative which supported a £17.5 million Agri-EPI Centre[8], which will provide a well timed focus to help develop these exciting developments and aid the drive towards a future of sustainable intensification at the farm. The Centre, which brings together expertise from academia and industry, aims to drive growth and support innovative ideas to help farmers and business

owners become more profitable and sustainable, in part by giving industry access to top academic minds and facilities. Data and smart engineering driven approaches are needed to support the farmer to reduce inputs, and increase efficiencies and yields. Academic institutions partnering with companies, such as AgSpace Limited, permit the fusion of innovative engineering with big data informatics techniques, which ultimately helps to provide the food requirements needed in the coming decades to feed the nine billion. The smart cities of the future need smart farms to sustain them.

There is also the Centre for Applied Crop Science (ACS), a £21.3 million government investment seeking to revolutionise how farmers manage crop threats including pests and disease, both in the UK and overseas. Giving farmers access to the best and most sustainable technologies, strategies and protocols to improve crop performance will make a real difference at the farm gate. Cranfield's involvement in ACS focuses on soil health – healthy soils underpin most agricultural businesses, as they support crop production by providing vital nutrients and water. However, soil properties also influence the viability and distribution of soil-borne pests, weeds and diseases. Soil management can influence these relationships, but there are significant gaps in our understanding of how different practices affect the persistence and transmission of biotic threats, and cost-effective guidance needs to be developed on how to manipulate the physical, chemical and biological properties of varied soils to optimise crop health and protection.

There is still much to learn, but by working together across continents, countries, institutions and businesses, and by testing new ideas and methods in modern facilities, we can make sure the impact we have on the field is significant and long lasting, helping to feed our rising population.

## SMARTER FARMS FOR THE FUTURE

Equipping the farmer with the skills and knowledge to deliver appropriate outcomes is paramount. Providing a synoptic overview of farm operations, agronomic scenario planning, soil management interventions, problem hotspots and in-field variation, yield optimisation, input minimisation, and better investment outcomes, will help deliver the sustainable intensification required.

Where these approaches have already had measurable successes in the UK arable farming sector, there is now great hope that similar approaches can be adopted and be used similarly to drive efficiencies in other key regions such as Africa, where soil conservation and land degradation pose real concerns. Integrated and sound land resource management approaches are needed.

And these advances will lead to others, such as with the new generation of high resolution multispectral satellite platforms, whose data is now being employed alongside other datasets, or the new generations of UAV and drones that can be used together in concert. Innovation, knowledge-sharing, industrial and academic collaboration, and multinational co-operation are needed to ensure we can feed the nine billion.

There is no underestimating the challenges that face us, and food security in the face of finite resources ranks high amongst them. Thankfully, there are many scientists, agronomists and practitioners from the land-based industries who are dedicating their efforts to the applied research and application required, working with growers in East Anglia to deliver these improvements.

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**Dr Stephen Hallett** is a Principal Research Fellow at Cranfield University with interests in soils information in environmental decision making. His research interests examine the role of soil in agri-infomatics; land resource management; geohazards and urban infrastructure; and environmental risk mitigation and soil-related impacts of climate change.

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