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FEEDING THE NINE BILLION

BOX 2: DR PETER MILLER

ShellEye project leader and Senior Scientist at Plymouth Marine Laboratory, Dr Peter Miller:

"Our team have been working closely with colleagues in aquaculture companies to extend and adapt approaches, which have been successfully developed for salmon farmers, so that they can also benefit shellfish farmers. This new approach to monitoring water quality around aquaculture sites, coupled with recent advances in satellite imagery and observations, will help build a multidisciplinary approach and tools to support the expansion of the UK's shellfish aquaculture industry".

satellite ocean colour sensors, such as MODIS or VIIRS, and in future OLCI, which was recently launched on the European Space Agency's Sentinel-3 satellite.

Alongside satellite information, ShellEye scientists at the University of Exeter have also incorporated biotoxin and microbacteria modelling forecasts into the bulletin service. By using meteorological data, and validated by direct sampling, the model can perform short-term predictions of microbiological activity in the water. The forecasts include *E. coli*, and algal toxins okadaic acid, pectenotoxins and dinophysistoxins; all of which have been linked to being hazardous to shellfish and often humans. ShellEye will combine these techniques to develop an alert capability expressly for algae that is potentially dangerous to UK shellfish and provide an enhanced, predictive approach to assist the local farmers in their stock management strategies.

THE FUTURE USE OF SHELLEYE

The leaders of this project are clear that the overall aim is to use the results of this research to develop a user-friendly service, providing farmers with helpful and timely bulletins on water conditions and potential risks (see **Box 2**). Importantly, all of this work has been carried out in consultation with partner shellfish farmers in pilot locations, allowing them to provide valuable knowledge and feedback on products to ensure these tools meet their needs.

To extend this user consultation further, the first interactive Stakeholder Webinar was held in November 2016 to present the project's progress and glean valuable feedback on the accessibility and usefulness of the developing bulletin service. The webinar was extremely useful for the project, with participating stakeholders providing important information on preferred format and frequency of bulletins, additional sensitivities and industry issues as well as highlighting future opportunities.

The recently funded second phase of the project will explore options for the long-term delivery of the service.

To help achieve this expansion and service provision, a number of new partner stakeholders have been welcomed to the project, having held the first project meeting in March 2017. Through this co-development approach, ShellEye aims to be piloting a useful and usable alert service by the end of the second phase that will help improve the economic mobility of farms and increase consumer confidence in UK shellfish into the future.

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The project, ShellEye, would value feedback, comments and suggestions during this development phase and this can be done through shelleye@pml.ac.uk. To be kept up-to-date with the progress of ShellEye and the development of the novel water quality bulletin service, interest can be registered at www.shelleye.org.

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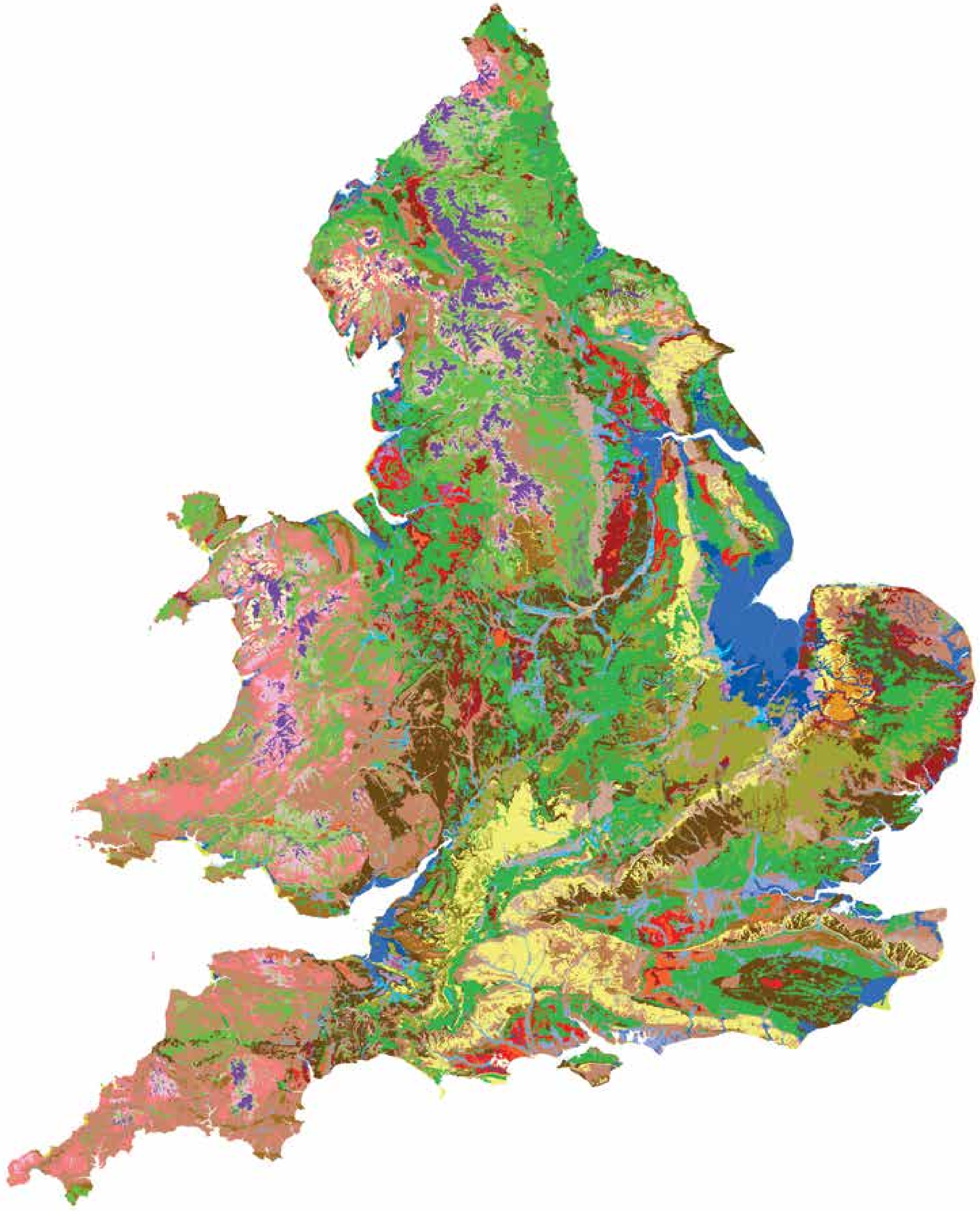
S.O.S. - Save our soil today to meet the food challenges of tomorrow

Dr Jacqueline Hannam analyses how soil research and disruptive innovation in farming techniques are contributing to meeting the food challenges of a growing global population.

It may be stating the obvious, but soil is where food begins. Around 95 per cent of our food comes from soil. But what if more food is needed, as is the situation today with a booming global population? Why not just increase the amount of agricultural land? The problem is there isn't actually much viable land left. In the UK, 70 per cent of the land area is already under productive agriculture[1] and globally this figure is around 40 per cent. Given many countries have significant natural constraints to agriculture (such as deserts, mountains and polar regions), or natural areas that society wishes to protect, the reality is that we have essentially run out of available land resources for growing food.

The only option is to grow more on the same (or less) land. It should be simple, after all there have been significant increases in crop yields over the last 50 years. This has been achieved by increased use of artificial fertilisers, better crop breeding programmes and crop protection – but all this has been to the detriment of soil quality.



▲ **Figure 1. Soils of England and Wales. (© Cranfield University) ‹www.landis.org.uk›**

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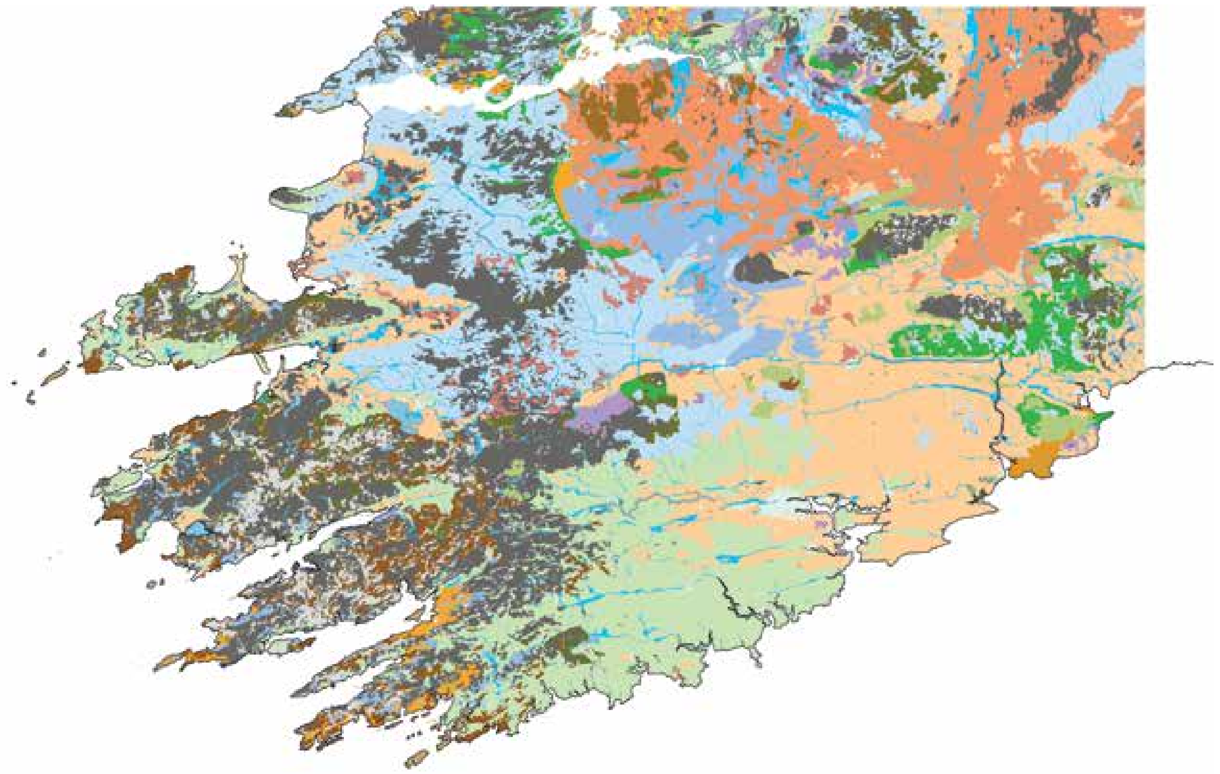


▲ **Figure 2. Detail of the Irish Soil Map part produced using machine learning. Irish National Soils Map, 1:250,000, V1b(2014). Teagasc, Cranfield University. Jointly funded by the EPA STRIVE Research Programme 2007-2013 and Teagasc. ‹http://gis.teagasc.ie/soils›**

It is estimated that most of the worlds soil resources are now only in fair, poor or very poor condition[2]. And in Africa (home to nearly a quarter of the worlds agricultural land), 40 per cent of soils are considered degraded, meaning they are less effective at supporting plant growth, resulting in lower crop productivity and crucially less food. It also means they have reduced capacity for other important environmental functions, such as water filtration and storage, biodiversity and carbon storage.

Soils are endangered through degradation. As soil forms very slowly (500-1000 years to produce a few centimetres), it is essentially a non-renewable resource. Degradation takes many forms; soil erosion, excess salts, nutrient loss, loss of organic matter and contamination. Agricultural practices can accelerate soil erosion, removing 25-40 billion tonnes of topsoil every year[2]. Soil erosion results in 15-30 per cent reduction in crop yields globally[3]. In England and Wales there has been a reduction in the organic carbon content of soils under arable agriculture over a period of 30 years (1978-2007)[4], although any potential effects on crop yields are likely to have been masked by fertiliser inputs. Nutrient depletion is limiting crop productivity in many other countries, particularly in Africa where effective application rates of artificial fertiliser are limited by economic viability. Altogether, this paints a gloomy picture when trying to deliver the food requirements for a predicted nine billion people by 2050. But unlike some past civilisations that collapsed as a result of resource degradation, we are at least aware of the problem and have a knowledge of potential soil management interventions that can help to stop and reverse this degradation.

UNDERSTANDING SOIL IN ALL ITS RICH COMPLEXITY

Assessing the current and future status and condition of soil resources is imperative to be able to make effective decisions on soil use and management. This requires a good handle on the spatial (and temporal) variability of soils and their properties, especially when considering in England and Wales alone there are over 700 soil types **(Figure 1)**. The assessments in a recent report on the status of the world's soil resources[2], were based on expert interpretation of primarily historical data collected decades ago during national soil surveys. Whilst there are efforts to update soil data, for example in Europe the LUCAS survey collected and analysed 20,000 soil samples across the EU-27, we cannot sample everywhere and often data is at a resolution that is not compatible for soil management decisions needed at the farm level.

Gaps in soil property mapping can be filled using machine learning methods to produce new soil information and maps (known as digital soil mapping). Machine learning is a technique that helps computers learn from existing data to predict new data, forecasts or trends. It is everywhere; embedded in voice recognition software like Siri and used to recommend products you might like to buy based on what you've already purchased online. Machine learning in digital soil mapping uses similar algorithms to identify patterns between ubiquitous spatial environmental data, such as satellite data and digital elevation models, and the resulting distribution of soils or soil properties in the landscape. The outputs can increase the resolution of already existing soil data or predict into areas where there is data scarcity (**Figure 2**). Although like the online pop up predictions of "what you might like to buy", machine learning doesn't always get it right as it still relies on enough relevant data to train the models effectively.

BETTER MANAGEMENT AND POLICY

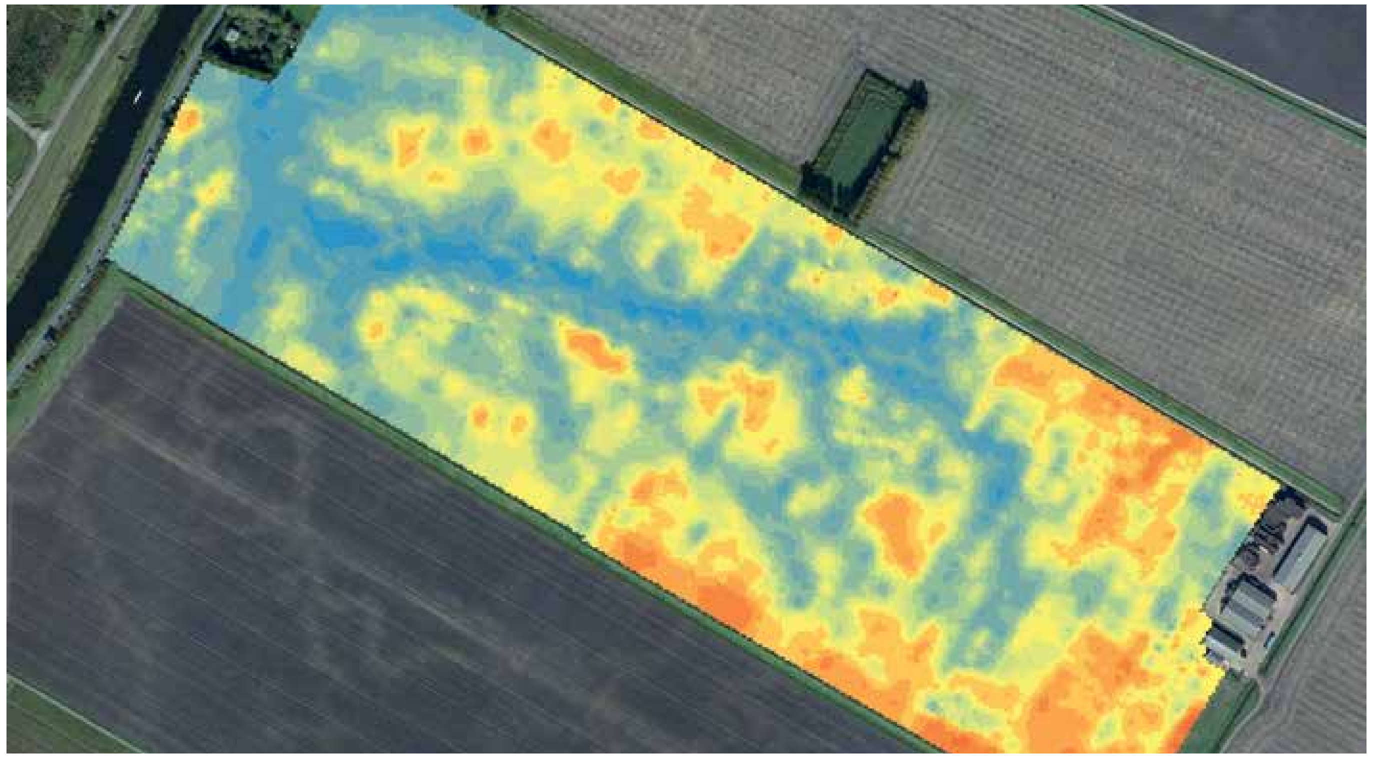
Once we have a better idea of how the soil resource is changing spatially, the question looms; how do we grow more food on the same amount of land but without damaging the soil further? There is no magic bullet, but it can be achieved through a variety of soil management interventions under sustainable intensification. These approaches focus on improving the soil condition, such as increasing organic matter, reducing erosion and targeting nutrient use and efficiency. Examples include:

1. Applying organic amendments (manure, crop residues, etc.) to increase soil organic matter.
2. Implementing cover crops (such as green manures) to reduce bare soil, while returning more organic matter and nutrients to the soil system and reducing erosion.
3. Minimising tillage to maximise organic matter and soil biology.
4. Reintroducing mixed farming and rotational grassland within arable systems.
5. Using precision agriculture for smart targeting of inputs (**Figures 3a & 3b**).

These approaches are already being implemented and empirical evidence shows improvement in both soil conditions and crop yields, but the effects can be inconsistent, variable or uncertain.

The variability in the effects of soil management interventions on crop yields is due to the local variation in soil type, climate and crop type. Thus soil management approaches need to be flexible and targeted to account for this spatial and temporal variability, but they also need to respond to policy requirements. The efficacy of these interventions should be monitored to:

▲ **Figure 3a. Google Earth image showing old drainage network (imagery © Getmapping plc © 2017 GeoEye © 2017 Intermap Earthstar Geographics SI O © 2017 Microsoft Corporation)**



▲ **Figure 3b. Variability in soil type within a field highlighted by electrical conductivity measurements (EC mapping © Gs Growers and Cranfield University Imagery © 2016 Getmapping plc).**

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“The challenge of feeding nine billion people by 2050 is immense, but so is our capacity to challenge and innovate.”

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1. ensure the soil system is not degraded further;
2. detect recovery from previous agricultural shocks;
3. adjust management practices accordingly; and
4. ascertain yield improvements.

FUTURE FARMING NEEDS TO BE COMPLEX

Soil is a complex system and some components respond rapidly to change (for example nutrient levels) whilst others are slower to show any effect (for example soil carbon). However, at present we are still largely limited to taking samples to measure soil parameters or using proxy measurements (for example near infrared spectroscopy) that also require calibration or large reference libraries with soil parameters.

The Holy Grail is real-time monitoring and direct measurement of soil conditions (nutrient levels, soil moisture, biological activity, carbon content, etc.) so that management practices can be tweaked to optimise the soil system. This will undoubtedly result in greater efficiency and increased crop yields. Considering that today’s fields are already monitored for some soil parameters and farming with robots is on the horizon, current sensor technologies do not measure everything, some are expensive and others are at low technological readiness levels. However, future progress in sensor development could mean that small, cheap devices can be buried in the soil to collect continuous measurements. These in situ measurements can also be integrated with other remotely collected datasets from satellites or drones. The future farm would be able connect data to decision support systems that translate the data into soil management options for the farmer. For example, a machine learning algorithm would be able to utilise all this available data and could predict which cover crops to implement for enhanced yields for the next crop in the rotation, based on the soil and crop requirements.

Innovative thinking and new approaches are needed because if we continue with the status quo, it has been estimated that soils will only support 60 more harvests[5]. To avoid this catastrophe we need to understand our soils better, and support farmers to try new approaches, many of which will be radically different to their current practice. Agriculture needs disruptive innovation to increase yields sustainably, and this can start with farming for soil. This requires a combination of new technologies and changing farming practices. These should be underpinned by effective knowledge exchange and collaboration between research, industry and agricultural practitioners, and crucially, be supported by agricultural policy that is flexible enough to encourage implementation of the adaptive approaches that are necessary to protect our soil resources. Most farmers recognise the fundamental value of their soil, but the numbers of practising ‘soil farmers’ needs to swell to ensure soils are able to effectively support sustainable increases in food production. This requires investing in soil for the benefit of the farmers and the population of the future. The challenge of feeding nine billion people by 2050 is immense, but so is our capacity to challenge and innovate. And remember, we need to save our soil now to save our future planet!

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