Our farming systems face immense challenges – including climate change, soil degradation, labour shortages and increasingly extreme weather. Yet food production will have to increase 60% by 2050, to feed the projected global population of 9 billion. We urgently need a new agricultural revolution, one that may completely overhaul ‘traditional’ farming practices.

**Building resilience**
The domination of intensive agriculture and heavy machinery has had disastrous consequences for soil health. Indeed, research has suggested that the UK’s soils can only support less than 100 future harvests. This has generated much interest in ‘soil-free’ systems, such as hydroponics (where plant roots are grown in a nutrient solution) and aquaponics (where waste produced by farmed fish supplies nutrients to hydroponically grown plants). At FFT, companies such as Lettus Grow were exhibiting the next level of soil-free growing: aeroponics, where plant roots are suspended in air and simply sprayed with a fine mist of nutrient solution. This significantly reduces the amount of fertiliser and water needed, and the plants also grow more rapidly due to the increased gaseous exchange around the roots. Since these systems typically operate indoors, the climate can be maintained at optimum conditions and the crop kept free of diseases without harmful pesticides. Although the capital outlay can be considerable, more crop cycles can be completed each year, reducing the cost per crop. Hydroponic and aeroponic growing systems require little specialist knowledge and could help communities affected by disasters or conflict to produce food self-sufficiently. Not every crop, however, thrives in these growing conditions: salad crops (including lettuce, cucumbers, tomatoes) and herbs appear the most suited.

Yet crops reared outdoors will need to be resilient against increasingly frequent extreme weather events, as the floods and droughts of 2019 aptly demonstrated.

One solution could be to embrace the power of arbuscular mycorrhizal fungi (AMF), which form natural symbiotic partnerships with plants, providing nutrients such as nitrogen and phosphorous in exchange for carbon. This can significantly enhance a plant’s vigour, yet AMF formulations developed for crops so far have had unreliable success. This can significantly enhance a plant’s vigour,
yet AMF formulations developed for crops so far have had unreliable success. This is likely due to these products having a ‘one size fits all approach’ that ignores the high specificity of microbial communities. Advances in high-throughput DNA sequencing however, are allowing researchers to uncover precise microbial networks around plant roots.

Companies such as MycoNourish are using this knowledge to produce bespoke formulations, tailored to individual plant species. They describe their research as akin to a ‘dating agency’ that matches up plants with their perfect fungal partners. The theory is that strong fungal networks surrounding plant roots will help mitigate against challenging environmental conditions, allowing more stable yields. Nevertheless, more research is needed on the impacts of AMF since they can have considerable effects on the host plant (influencing gene expression, development time and disease resistance) and can become parasitic under certain conditions.

At FFT, the spotlight was also shone on a more controversial approach to increase crop resilience: gene editing. This is distinct from genetic modification, where entire genes (often from unrelated species) are introduced to produce a genetically modified organism (GMO). Gene editing methods, which include the powerful CRISPR-Cas9 method, are more subtle and precisely target specific genes, making changes that can be as small as a few base pairs of DNA. This can silence negative traits or amplify positive ones, such as disease resistance or drought tolerance. Ultimately, gene editing could allow plant breeders to rapidly develop new cultivars in response to changing environments, or plants that don’t require drenching in pesticides and fertilisers.

They could even feasibly produce gluten-free wheat suitable for those with coeliac disease. But despite this promise, progress in using gene editing remains in a regulatory deadlock since the European Union’s Court of Justice ruled in July 2018 that gene edited crops would be treated with the same stringent controls as GMOs. Brexit, of course, could enable the UK to pursue a different agenda, but would consumers accept this given the strong antipathy towards GMOs?

This may be overcome if gene editing is dissociated from genetic modification and its benefits clearly communicated: few consumers, for instance, are happy with the idea of food crops being heavily sprayed to protect them from disease, yet gene editing tools could reduce the need for this. Gene editing techniques are already being used in medicine to develop new therapies for diseases such as leukaemia, sickle-cell anaemia and cystic fibrosis. Many consumers also don’t realise that GMO crops are already part of our food chain, since much of the soybean imported to the UK for animal feed is GMO soybean from the USA. In any case, the consensus at FFT was that, should these techniques be used within agriculture, consumers should be given the right to choose gene edited food products through clear, unambiguous labelling.

Enter the robots
Future generations will no doubt look back in astonishment at our heavy-handed and wasteful use of resources; drenching whole fields with chemicals and applying the same feeding and medical regimes to entire herds of animals.
'Precision farming' is one of the biggest trends in agriculture, with advances in robotics and big data allowing farmers to focus directly on problem areas. There is already a wide array of digital devices for livestock that constantly monitor key indicators such as activity, eating patterns and temperature, including the SMARTBOW ear tag and Silent Herdsman neck collar.

Subtle indications of a developing health condition can thus be picked up early, allowing swift intervention before they worsen. Drones have also generated much excitement, being able to rapidly fly over fields that would take hours to cover at ground level. They also offer a highly accessible way for farmers to collect data to aid decision making; in many cases only a shop-bought drone and a smartphone is required. Drone AG, for example, has developed an app that links up to the camera on a drone to produce a map that highlights healthy crops and weeds.

Nevertheless, drones have many disadvantages, for instance regulations on their use, the need for good connectivity and their unsuitability in windy conditions. As such, many companies are investing heavily in ground-operated machines, that can assess and care for plants and animals on an individual basis. The Small Robot Company, for instance, are developing a model for arable farms involving three robots (Tom, Dick and Harry), coordinated by a central artificial intelligence engine (Wilma). Tom assesses the crops each day, feeding back key data relating to health and development to Wilma, who can then instruct either Dick to apply fertiliser or remove weeds; or Harry to plant new seeds in a predesignated spot.

Systems like these based on small, lightweight robots could have manifold benefits, including reduced soil compaction; precise, non-chemical weeding and more efficient use of fertilisers. Exact planting and digital crop maps could also enable mixed farming practices that include plants that can help restore soil health. And of course, they could free up valuable time for the farmer. Perhaps there will even be a day when the farmer can have a lie in, leaving their robot workers to do the early-morning scout around the fields?

At FFT, Duncan Forbes presented the Agri-EPI Centre’s ‘Dairy farm of the future’ in Somerset, a new £1.3 million, 180-cow facility trailing the latest dairy technologies. Everything is fully automated, yet the farm does not appear as an impersonal, animal-hostile environment. Instead, with data driving each decision and the animals monitored individually, high levels of animal welfare can be achieved. For instance, as soon as cows are ready to be milked, scanners detect their readiness and prompt a guiding system towards the robotic milkers. The walls of the building automatically adjust to changes in wind speed, temperature and humidity to maintain a pleasant, controlled environment.
A suspended automated feed system can deliver tailored feeds to different groups of cows: the aim is to link this to data about the energy and protein content of the outdoor pasture, allowing deficiencies to be supplemented accordingly. These systems – whilst impressive – prompt the question as to whether rural livelihoods are under threat. At FFT, the assurance was that, for the near future, robotics and automated systems will not replace farmers completely, but play a supporting role in aiding decision making. Some even argue that these technologies will potentially create a wealth of new careers with greater appeal to digitally-native younger generations.

For that is one of the key challenges farming faces: attracting new entrants into the industry. Perhaps farming is unfairly stereotyped as a menial, laborious vocation when – as the FFT expo showed – it is a sector utilising the very cutting-edge applications from science and technology. Hopefully, they can inspire a new generation to become agriculturalists. After all, feeding people is a universal need... can there be a more worthwhile cause than that?

References and article available online at fsjournal.org/features/farms-future

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Cows feeding with automated feeder: At the South West Dairy Centre, every aspect is automated from feeding to milking (Photo credit: Agri-EPI Centre).