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Game-changing technologies for agriculture and the future farm

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Elizabeth leads the Department for International Trade (DIT) Agri-Tech team that promotes the investment and trade of innovative agricultural businesses, products and services. She started her career with 10 years' experience at the International Center for Wheat and Maize Improvement (CIMMYT) in Mexico. Elizabeth has since been a lecturer at the University of Edinburgh and held a number of senior posts across UK Government related to innovation and agricultural technologies. These included providing advice to three Government Chief Scientific Advisers on food and water security issues; responsibility for programme delivery of the former Department of Trade and Industry (DTI) technology programme; and managing Department for International Development (DFID) research programmes for agricultural production systems in low- and middle-income countries. She also led the Government Office for Science review of how the Department of Health manages and uses science to inform the development of policies. Elizabeth is also General Secretary of the TAA and a technical editor of Ag4Dev.

Agricultural technologies (Agri-Tech) are the key to feeding and fuelling the planet

Agriculture is not just farming…

- we touch or use it every day – leather, cotton, food, drink, biofuels – just to name a few; or
- we work in the agriculture sector – over 450,000 people are employed in the sector in the UK.

What's the global problem?

- The world's population is expected to rise from 7 billion to 9 billion by 2050 and could reach 11 billion by 2100.
- Diets are changing with more meat and dairy products being consumed.
- About 40 percent of food is lost post-harvest.
- Over 1 billion people live in extreme poverty.
- More than 75 percent of the extremely poor live in rural areas – primarily dependent on agricultural production.
- About 800 million people go to bed hungry each night.

This means that there is an increasing demand for land, energy, water, feed, fertilisers and other resources. Agriculture is also competing for resources while urbanisation and industrialisation put more pressure on land. In addition, there are environmental threats that mean we need to adapt to environmental change, changes in water availability and less-predictable weather patterns.

Agriculture contributes to eight of the United Nations' Sustainable Development Goals: 1: no poverty, 2: zero hunger, 3: good health and well-being, 8: decent work and economic growth, 12: responsible consumption and production, 13: climate action, 14: life below water and 15: life on land.

These challenges mean that new agricultural science and technology are needed.

What do we mean by 'Agri-Tech'?

Agri-Tech improves the productivity and sustainability of agriculture (arable/livestock, horticulture, aquaculture, forestry, equines and pets) covering input supply/nutrition, farming/ecosystem management and animal welfare/health. It is supply-chain oriented and includes on-site storage and processing of food and non-food products.

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The UK offer

The UK Government is working with the scientific community, and food and farming industry so that the UK can:

- become a world leader in agricultural technology, innovation and sustainability;
- exploit opportunities to develop and adopt new and existing technologies, products and services to increase productivity; and thereby
- contribute to global food security and international development by ensuring that safe, healthy, nutritious food is affordable and accessible to all.

Investments include the 'HMG (Her Majesty's Government) strategy for agricultural technologies' (£160 million over five years) in the Agri-Tech Catalyst and the four new Agri-Tech Innovation Centres, which have improved the flow of ideas and solutions from laboratory to farm; and the recently launched 'Industrial strategy challenge fund transforming food production' initiative (£90 million) which aims to enable greater take-up of innovation on farms.

The 'Agri-tech Catalyst programme' (£70 million) has funded over 100 research and development (R&D) projects to improve agricultural productivity and to stimulate businesses and academia to work together.

The four world-class Centres for Agricultural Innovation (£90 million) are now established to translate our world-leading agricultural innovation into commercial opportunities for UK businesses:

- Agrimetrics is utilising data, science and modelling to build a more efficient food system;
- Agricultural Engineering Precision Innovation Centre (Agri-EPI) is exploiting opportunities in precision agriculture;
- Centre for Crop Health and Protection (CHAP) is revolutionising how farmers manage crop threats including pests and diseases;
- Centre for Innovation Excellence in Livestock (CIEL) is creating new livestock technology.

Three specific strengths of the UK offer are:

1. **World-class science**. The UK has some of the longest established agricultural research institutions in the world. It is home to 100 science parks, three of the top 10 veterinary schools in the world and is world leader in the scientific study of both plants and animals. Highly skilled talent, along with educational and scientific excellence has created an outstanding culture for research and development in collaboration with industry. This has helped deliver new knowledge and many innovative products, practices and technologies.
2. **Progressive farming supply chain**. The UK led the agricultural revolution of the 18th century, introducing innovative farming practices from crop rotation to novel equipment. It is home to some of the world's best farmers who produce highly sought-after products. Many of these farmers already integrate Agri-Tech into their work with excellent results. They recognise the potential to do more to maximise the uptake of Agri-Tech in increasing productivity, through the use of precision agriculture, to drive efficiency, maximise yields, protect the environment and increase profitability.
3. **Dynamic business environment**. It is easier to do business in the UK than in any other major economy in Europe (according to the World Bank). Not only is setting up a business very quick and easy (a couple of days), but the Government incentivises collaboration between industry and science with R&D tax credits and the Patent Box, supported by strong intellectual property (IP) regulation and quality protocols for standards.

Integrating the UK's world-class science with progressive food and farming businesses provides potential rewards in: increased productivity, maximising returns on investment, business growth opportunity, job creation, sustainable intensification of agriculture, and contributing to global food security.

Agri-Tech sub-sectors with opportunities and UK strengths in capability include the following.

- **Plant science**, the study of plants, including their growth, structure, physiology, reproduction, ecology and pathology, as well as their economic

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use, suitability for intended use/purpose and cultivation by humans. Opportunities from the UK include its world-leading plant science research, superb university sector and institutes able to replicate climate and culture conditions found throughout the world, and robust IP protection and tax relief for patents developed in the UK. Strengths in capability include: agrochemicals, biological systems, genetics, agronomy solutions, nutrition, disease control, novel products, greenhouses, and novel growing systems.

- **Animal science**, the development of products and services relating to animal health and welfare, including those related to prevention, detection, characterisation, management and treatment of animal diseases and animal health. UK veterinary science ranks worldwide at No. 2, with eight veterinary schools and more international animal disease reference centres than any other country. Edinburgh has the largest concentration of animal health researchers in Europe. Strengths in capability include: dairy equipment, vaccines, genetics, diagnostics, pharma, nutrition, digital innovation, and companion animal welfare.
- **Aquaculture**, the intensive farming of fish, shellfish, plants and algae in freshwater, coastal waters and onshore. Innovation areas in the UK include: breeding, genetic and trait selection for fast growth, aquafeeds, plant proteins, terrestrial animals and oils, health, vaccines, infrastructure, recirculating aquaculture systems, offshore systems and aquaponic systems.
- **Precision agriculture**, the use of technologies to allow farmers and growers to make more informed decisions on cropped areas, animal husbandry and land management. Effective application of appropriate precision technologies enables fewer inputs (water, fertiliser, energy) to give higher yields. Many business opportunities from other sectors exist in precision agriculture (*eg* space, telecoms, information and communications technology, big data, chemicals and engineering). UK strengths in capability include: big data, artificial intelligence, robotic weed control cultivators, measurement of critical soil parameters, unmanned aerial vehicles (UAVs, *ie* drones), robotics, automation, data systems, sensors, management systems, precision engineering and modern tractor design concepts. These are used to improve farming methods through sensing and positioning, automation and machine control, increased accuracy of application, data handling and transfer, wireless technology and decision-support systems.

Game-changing technologies

The global revolution in digital, robotics, diagnostics/detection and new sources of protein provide new opportunities to improve sustainable farming methods for the future farm, while completely new approaches to farming such as vertical and controlled environment farming are being developed.

Digital

The digital agricultural revolution will fundamentally change the way farmers manage their farms and do business. This will both threaten and present new opportunities for existing and new agricultural businesses.

Some facts:

- UK technology is present in 95 percent of the world's mobile phones;
- the UK is Europe's largest e-commerce market;
- £26 billion has been invested in UK tech over the past five years;
- 18 of the 47 European Unicorns are in the UK; and
- the UK is the world's third-largest digital tech sector, after Silicon Valley and New York.

Data from many different internal and external sources – including sensors, weather, on-farm treatments, crop inputs, yield data, fuel consumption, disease prevalence and prediction – will need to be integrated into a cloud portal allowing sharing of selective data with different areas of the farm and supply chain. Access to this big data and predictive analysis will propel the growth of the industrial internet of things (IoT) in agriculture. This will be supported by

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communication technologies and robotics that ensure a smooth flow of information on the farm with decision-support systems to allow smarter farm management and increased productivity.

An example of digital application is Felcana, a new generation of digital pet care, with 24/7 monitoring, telemedicine services and healthcare treatments to support pets in receiving better, more efficient veterinary care. The system is designed by experienced vets and developed by inventive engineers.

Robotics

Dexterous cognitive robotics are being developed to transform labour-intensive tasks on farm from sensor/data-collection tasks to agricultural operations such as:

- soil and crop scouting
- robot tractors
- harvesters to replace human pickers
- smart cultivators
- laser weeding
- selective and precision targeted pest and disease treatment
- logistics and materials management
- livestock – care, treatment,surveillance, mustering and feeding.

An example is the world's first 'Hands Free' hectare developed in partnership by the Agri-EPI Agri-Tech Innovation Centre, Harper Adams University and Precision Decisions Ltd. One hectare of barley (last year) and wheat (this year) has been sown, grown and harvested by automatic and robotic operations without a single person stepping on the field.

Diagnostics/detection

An increased focus on prevention (vaccines), prediction (genetics) and detection (diagnostics) will shape the future of farming, providing the need for new, alternative technologies that will be more in line with evolving customer choices. New diagnostics/detection technologies developed in the UK with application globally include the following.

- Fungi Alert, an in-field early detection device to detect spores of pathogens in soil and water before they infect plants.
- IoLight, a lab-specification field microscope with 1 μm resolution in a pocket device: images and videos are shared on a tablet – low cost, simple to use, and web-connected for remote diagnosis.
- Nanopore technology, a portable DNA sequencer that rapidly identifies crop infections to allow monitoring of outbreaks, precise deployment of agrochemicals and has applications for crop breeding (including orphan crops).

Sustainable protein

Aquaculture has the potential to supply protein that is needed for a growing global population likely to demand 75 percent more protein by 2050 than is currently available. Fishmeal is recognised as a high-quality aquaculture feed ingredient in many fish feeds as it increases feed efficiency through enhanced nutrient uptake, digestion and absorption (Miles & Chapman, 2018). Wild-caught fish populations are declining due to regulatory and environmental factors and overfishing, resulting in fishmeal supply constraints. Fishmeal substitutes such as vegetable proteins are less desirable due to lower protein content and side effects on fish (Spinelli, 1980). The availability of a high-quality non-plant fishmeal replacement is essential to optimise aquaculture production to meet future global protein demand. Examples of innovation in sustainable protein by UK-based companies include the following.

- Entocycle, an automated circular process that produces black soldier fly larvae which are high in protein and essential amino acids.
- MiAlgae uses by-products of the whisky industry to grow micro-algae which can be used to sustainably farm fish.
- Calysta has a revolutionary platform for producing 'FeedKind', a natural, non-genetically modified (GMO) high-quality protein with a nutritional profile virtually equivalent to fishmeal, derived from natural microbes using a fermentation process with methane, with

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patents and approval for sale in the European Union. Production requires no agricultural land, uses 75 percent less water than crops and is a potential additive to the human food chain.

Vertical farming

New agricultural businesses see increasing opportunities to produce more food on less land with fewer inputs and with less impact on the environment. This means that, in addition to the growth of new aquaculture production systems, new businesses are looking at vertical farming as an option for more rapid growth and extension of growing seasons for high-value crops with lower water and labour requirements. This involves the integration of several different technologies, including LED lighting regimes, growth platforms, hydroponics, aquaponics and automation.

- Grow-Up Urban Farms. Aquaponic system growing salads and herbs for high-end restaurants within three weeks using water from tanks rearing black tilapia which are also sold after six months.
- Aponic. Remote control vertical soilless growing systems recirculate nutrient mix from a reservoir to vertical grow tubes and can be used within old shipping containers.
- Airponix Ltd. Smart, soilless Agri-Tech system with nutrient cloud (fog generation with inkjet print-head) and low-cost protected growth chambers for potatoes, sweet potatoes, raspberries, wheat, tomatoes and grape vines.

Integrated solutions in supply chains

Industry innovation is usually siloed and incremental (chemistry and seeds, food, machinery, data, sensors and animals). Increasing connectivity means that it will become progressively more difficult to develop discrete technological solutions for farming. Integrated solutions of innovation across the different components of a supply chain will become even more important and can make a large difference. Three case study examples are given: innovation in strawberries, the UK livestock traceability programme and the cold chain supply chain.

Innovation in strawberries is a clear example of how different types of technologies across the supply chain have helped to not only increase production, but also extend the growing season, including:

- **Genetics.** Range of June-bearers and everbearer genetics with overlapping seasons to provide excellent fruit quality over a prolonged period, producing high-yielding cultivars with large fruit size and low percentage waste, and improving disease resistance. The national programme for strawberry breeding at East Malling has released 39 varieties for all sectors of the strawberry industry since 1988, with over 250 million plants of these varieties sold, mostly in the UK and northern Europe, but also in Republic of Korea and the USA.
- **Multi-span polytunnels.** Engineering R&D of structures and plastics, such as the use of diffusing additives, and improved thermal properties.
- **Growing systems.** Soilless systems, table top, peat, coir, and nutrition delivery.
- **Production and scheduling.** Propagation, chilling, storage to extend production season, perennial to two-cycle production, ergonomics of picking.
- **Crop protection.** New pests and diseases under polytunnels, biological control adapted from elsewhere (tomato/flowers), biological understanding of target pests, withdrawal of soil-sterilant chemicals, and biofumigant alternatives.

The 'UK livestock traceability programme' is a public-private partnership – Department for Environment, Farming and Rural Affairs (Defra), National Farmers Union (NFU), National Office of Animal Health (NOAH), Agriculture Horticulture Development Board (AHDB) – to develop the *Requirement for Information Documents* based around a range of technologies (FarmWizard Magic Livestock Management, TGM Software Solutions, Unitas Poultry Manager, Dalton Tags, Allflex). Several third-party systems are also being developed to integrate individual animal data with herd health records and veterinary medicines. This is leading to the development of:

- robust, visible, tamperproof radio frequency identification (RFID) enabled tags;

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- various RFID reader devices – wands, weighbridges, sorting gates, etc;
- standardised 1D and 2D barcoding systems; and
- integrated databases for rapid and reliable data exchange.

These systems and technologies will address the five key traceability requirements in legislation for the cattle farmer:

1. Registration by the farmer, as a keeper, of every land holding used.
2. Identification of each animal owned, with passports corresponding to animal identification tags in accordance with EU legislation.
3. Accurate up-to-date record-keeping.
4. Complete documentation for all livestock movements.
5. Notification of all livestock movements from birth to death on each holding to the British Cattle Movement Service (BCMS).

The 'Cold chain' supply chain is an integrated, seamless and resilient network of refrigerated and temperature-controlled pack houses, distribution hubs and vehicles used to maintain the safety, quality and quantity of food while moving it swiftly from farm gate to consumer.

Currently, a land area twice the size of Australia is used across the globe to produce the food lost post-harvest, with water consumption equivalent to 280 km^3 of water a year (three times the volume of Lake Geneva). A transport refrigeration unit consumes up to 20 percent of a refrigerated vehicle's diesel, can emit up to six times the nitrous oxide and 29 times the particulates of a Euro 6 engine, and produces significant amounts of carbon monoxide.

The UK is at the fore of clean cooling with expertise on the 'cold economy' at the University of Birmingham, Heriot-Watt University and others, which have been leading research to develop the integrated strategies and novel technologies to manage the cooling load cleanly, efficiently and affordably within the transition to renewable energy. Innovative technologies include solar-powered off-grid storage and Dearman piston engines powered by liquid nitrogen – generating both cold and power – now being trialled with Sainsbury's.

Future farms

With the rapid development of technologies, farming practices will change in the future. Different models are being developed in Africa, Asia and Latin America to help farmers access these new technologies and practices.

- **Africa:** In Zambia, an industry initiative led by AGCO and partners (Farm Facts, Harper Adams University, Precision Decisions Ltd, Sainsbury's, Seed Co, Syngenta, Valley, Yara) is not solely a research or commercial farm of 150 ha, but has a training centre for education and seeks to unlock the value of technology through partnerships across different sectors to deliver supportable turnkey systems for farmers.
- **Asia:** In India, the EM3 Answer uses a farming-as-a-service (FAAS) uber model that helps farmers access high-end tools and technology through a Samadhan service centre with all the equipment owned and operated by Samadhan staff, hired locally. Each centre employs 10-15 people, who can serve up to 2,000 farmers in a 5-10 km radius with up to 5-10 tractors and 25-30 pieces of equipment (harvesters, power harrows, laser-levellers). Farmers can schedule the service by visiting the centre or through a phone call. They get a specific time slot and pay on an hourly or area basis. With local staff, free demonstration of new technologies, and timely and professional service, FAAS adoption rate is rising. As an example, Bal Kishan Meena, 54 years old, is a father of three, who owns 30 acres and manages 100 acres. Among EM3's first customers, he has used a range of services including the paddy transplanter, crop harvester and the laser-leveller. Using the laser-leveller has helped him save water use by 20 percent and boost crop output by 2-4 percent.
- **Latin America:** In Paraguay, the Agri-EPI Innovation Centre is collaborating with a farm practising silvo-pastoral systems for beef and dairy as a launchpad for UK Agri-Tech to be trialled in situ and then deployed in Paraguay and other South American markets. Opportunities to improve productivity are identified and then appropriate technologies

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used, for example managing cattle nutrition more precisely by installing systems to monitor cattle, with the potential to reduce calf losses and increase profit margins.

Each and every country will need to explore how to produce more food sustainably, in a changing climate, while protecting the environment. This is a tall order, but not insurmountable if governments, businesses and academia work together in a global coordinated effort, harnessing technology from a range of diverse sources, to sustainably produce more with fewer inputs and resources.

The DIT Agri-Tech Team

The Department for International Trade (DIT) was established in July 2016 to secure the best deal for the UK as the country establishes new trading relationships worldwide. The Agri-Tech Team is the first port of call for overseas companies looking for investment opportunities in the UK and for UK-based companies seeking assistance to expand their international business. The team champions the role of Agri-Tech in strengthening agribusiness success in both UK exports and investment; and is helping drive the sustainable intensification of agriculture to provide global access to sufficient, safe, healthy food.

The unique hybrid team of private-sector specialists and civil servants combines the expertise and knowledge of business, academia and government from across the UK and the international Agri-Tech sector.

Working alongside DIT's global network of in-country experts with market insight in over 100 markets, tailored advice and support is provided to businesses, helping to drive demand for British goods, services and inward investment opportunities. Trade focus markets include: India, the Mediterranean (France and Spain) and Africa (Angola, Ethiopia, Kenya, Nigeria, South Africa, Tanzania, Uganda and Zambia). Other markets for trade include Argentina, Brazil, China, Colombia, Mexico, Paraguay and Uruguay. Investment focus markets are Australia, Germany, India, the Netherlands, New Zealand, Portugal and Switzerland.

The DIT Agri-Tech Team also leverages Government influence to address barriers to trade and accelerate routes to market for UK companies looking to export their products to new markets.

Key areas of focus are plant sciences, animal health, aquaculture and precision agriculture, but other value opportunities are supported on request.

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