A Nuffield Farming Scholarships Trust Report

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Technology adoption
by small and medium sized agricultural businesses in the UK

Michael Thomas Ratcliffe

May 2019

NUFFIELD UK

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ISBN: 978-1-912059-78-2

Published by The Nuffield Farming Scholarships Trust
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Date of report: May 2019

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Technological adoption by small and medium sized agricultural businesses in the UK
Scholar	Michael Thomas Ratcliffe
Sponsor	The Richard Lawes Foundation
Objectives of Study Tour	● Develop a detailed global perspective regarding current technology use in agricultural operations, in particular that of small to medium sized practitioners ● Identify technologies that are likely to dramatically change the way agriculture is currently operating ● Provide positive examples of organisations/countries that are delivering technology that meets the needs of today's practitioner in a fast and effective way ● Investigating the driving forces behind successful countries
Countries Visited	England and Wales, Holland, Germany, Czech Republic Cambodia, Spain, Luxembourg
Messages	● New technology is aimed at removing the *thinking* demands of farming (i.e. precision ag). You know you can't outlift a tractor. Similarly you won't out-think new automation (at its specific task). ● Over the course of the next 20 years technology will change the way we manage and work our land more than it has changed over the last 200. The speed of development/changes in this technology will be at mobile phone-like advancement rapidity. ● Choosing a technology will present challenges as new technology is often over/under hyped, and grasping its true capabilities/usefulness is no simple feat. No matter the size of your operation, get out there to network, visit other farms and understand your industry. Unbiased feedback from actual practitioners will be key to successful technology adoption. ● We have many bright minds in the UK's academic system who could make real contributions to British agriculture in the area of technology but we do not reward them for industry impact, and doing something useful would be career suicide for many academics. Other countries like the Czech Republic have embraced and rewarded institutes with high industry impact and are seeing major industry-driven developments from this mentality.

EXECUTIVE SUMMARY

In the course of the next twenty years technology will change the way we manage and work our farms/land more than it has changed over the past two hundred. The study topic is centered around technology development and how to ensure small to medium farming operations are not left behind as technology develops.

The study explored what new technology was being employed in agriculture overseas, and how much of this technology, delivery strategies and development policies could be put to good use in the UK. Holland was visited because it is renowned for leading the way in the delivery of agricultural technology: the Czech Republic because their academic institutes have considerable impact on their progressive agricultural industry: and Kenya and Cambodia, each in their development stage in regard to technology, to see how they were taking advantage of technology and to identify examples of leapfrogging.

The technology development and adoption cycle has many key players, but I concentrated on:

- **Government policies** on Ag-tech
- **Technology development**: who is involved in developing technology, what technology is likely to be available soon
- **Technology adoption**: if we have access to a useful technology how do we promote adoption and ensure that the right technology is reaching the right people

The study established that the UK can implement small changes to make large strides in ensuring technologies are a part of leading positive changes for farms of all sizes. For this to happen it is important that farmers, policy makers, academics, consumers and ag tech companies work closely together to ensure this technology is developed to solve farmers' needs and that it reaches them in timely and affordable fashion.

Main findings were:

Ability: Just as the advent of the tractor changed the way physical strength was viewed/used on farm, developments in computational vision, artificial intelligence and access to large amounts of data are allowing the creation of powerful tools aimed at removing the mental/cognitive demands of farm-related tasks. The ability of a human to out-think/perform this technology will be akin to trying to outlift a tractor.

Motivation: These technological advancements are promising because they not only reduce the cost of production but also increase quality whilst reducing environmental impact.

Development: Many of the technologies that will have big impacts on agriculture are already within our academic institutes. However, traditional academic Key Performance Indicators (peer review papers), and a view of industry partnerships all seen as a tick box exercise, are reducing these institutes' ability to deliver agricultural industry impact when compared to countries with more industry-orientated universities. If the UK wants to have world-leading technology it should start by promoting practitioner/academic partnerships, whilst ensuring our academic institutes have funding allocated to make measurable industrial impact.

Adoption: The biggest indicator of a farm's ability to adopt technology that meets its need is networking and awareness of technology being used by others in their sector. Promoting peer-to-peer farm networking would reduce the number of farmers left behind - or adopting technology that is soon to be leapfrogged.

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1. Personal Introduction


Figure 1: The author, Michael Ratcliffe

Being raised on a modestly sized but diversified family farm in the North West of England gave good insight into the issues small agricultural enterprises face and how resilience is essential for success. Like many young people in struggling agricultural households I was persuaded by family members to pursue a career outside of agriculture. I followed my second passion, engineering. This exit from agriculture was, however, short lived. Following an undergraduate degree in mechanical engineering and a postgraduate by research in electrical engineering I was pulled back into agriculture by my love of making things.

In 2012, after an overland expedition in the Sahara desert, I became interested in Aquaponics: the production of fish and vegetables in a closed loop system. During this trip I noticed that parts of the Sahara desert had surprisingly shallow water wells and good transport networks. These, I naively thought, coupled with the intensity of the sun, was all a productive farm needed apart from soil.

I built a medium sized aquaponics unit on the family farm to test Aquaponics out for myself, to see if it really was all it was claimed to be. It turned out it was a hard system to manage both knowledge- and time-wise, so I put my engineering degree to use and automated the system to free up my time and reduce the complexity for family members running the system whilst I was away from the farm.

This automation was carried out on a shoestring budget using cheap commodity components, and coded in a hurry during a few lunch breaks at the office. It may not have been perfect but it worked for my needs. I threw the code and a wiring diagram up online under an open source [free] licence in case it was useful to other people as a starting point for their own systems. Suddenly I became the go-to guy for Aquaponics automation and found myself selling automation to aquaponics operators around the world and getting a bit of attention from industry leaders: e.g. the testimonial below.

AVF: Vertical Farming
Henry Gordon: *"Michael Ratcliffe's Project Portfolio is the Ideal Response to the Needs of Growers Around the World"*

This reputation wasn't because I'm particular gifted or the technology was groundbreaking in nature. I was simply solving a real problem that I had because no off-the-shelf solutions met my needs as a small operator at that time. From this experience I was able to see that there was a real need for better automation/technology in small to medium farming enterprises and started working on simple and affordable solutions which reduced demands on time and knowledge in glasshouse food production. This led to the creation of a company, the AquaponicsLab.

I enjoy building things and most of my free time is spent building robots just for the fun of it, or attending hackathons. If I get too much spare time, regrettably I'm the kind of person who'll spend 10 hours building a robot to replace a 10-second task like brewing coffee. To avoid this happening, I keep longer holidays free for camping, overland trips, reading, dog walking, and, in a past life, playing rugby.

2. Background to my study subject

My study tour subject was "*Technology adoption by small and medium sized agricultural businesses in the UK".* In this context the term "agricultural" was used generically to cover farming, horticulture, aquaculture and forestry.

Being raised on a small farm I noticed how mechanisation has pushed the minimum viable farm size up year on year as technological offerings cater for the larger farms. Smaller operations thus have to expand, diversify or expire. This sparked my interest in technologies that can reduce the minimum viable farm size: that is, how smaller farms can stay profitable and competitive without constant expansion.

For example, my own family farm, to which I refer several times during this report, covers only 14 acres in Lancashire and is not actively producing these days. Yet at one time it employed 2 workers (including a family member) plus a further 2 people as butcher and greengrocer respectively, along with a handful of part time employees. Now it only generates income from non-farming activities: I would love to change this.

The success of smaller farmers should matter to farmers of any scale. Public perception of farming in the UK does not reflect the great work farmers are doing as an industry. Many of the consumers whose needs we are meeting, unaware of the immense progress being made year on year to ensure agriculture is environment-enriching, hold views on agriculture that are out of date. Misleading views are provided by anti-agriculture organisations. This negative perception of agriculture by the general public is, in my opinion, the biggest thing holding British agriculture back.

> *Whilst the majority of British farmers are excelling, the industry's image is based on those lagging behind.*

Having the public's support and a good public image is important if we are to entice quality people to take up a career in agriculture, pass policies that allow us to farm to the best of our abilities and sell that produce for a reasonable profit domestically. Whilst the majority of British farmers are excelling, the industry's image is based on those lagging behind.

So on my study tour I wanted to explore what new technology was being employed in agriculture overseas, and how much of it could be put to good use in this country by our small farmers.

I looked at the whole technology cycle:

- Government policies on Ag-tech.
- Technology development, who is involved in developing technology, and what technology is likely to be available soon.
- Technology adoption, so we have access to a useful technology. How do we promote adoption and ensure that the right technology is reaching the right people?

Each will be discussed in the following chapters. But first I will detail the countries I chose to visit in order to study the technologies they were using, and my reasons for choosing them.

3. Travels

During the course of my Nuffield Farming Scholarship I have been fortunate enough to travel to multiple countries and get first-hand experience of technologies, techniques and farming practices used in a wide spread of agricultural sectors; and further understand the food supply chain from producer to consumer. The table below summarises each country visited and states why primarily it was chosen. Although the primary reason was to visit agriculturally-related organisations and operations, I also found it interesting to investigate other issues that fitted into the timetable:

- Investigate other industries - when the opportunity presented - to search for transferable technologies, techniques and gauge our development as an industry in comparison.
- Interact with people at key locations (Farmers' markets, farm shops, supermarkets) to understand the issues, thinking and views of the final user/consumer side of the agricultural industry.

Where	Date	Reason for Visit
Spain Majorca	January 2017	Majorca being a relatively small island imports a sizable amount of its fresh produce. What is holding back its domestic producers from meeting local demand?
England	Various	Top up knowledge of British farming operations to better give contrast when travelling abroad. Present and participate at conferences such as COST 2018 and network at general agricultural events.
Cambodia	May/June 2018	After assessing the implementation of technology in many developed countries and seeing a glimpse of African technology use during the GFP tour, I believe visiting a developing Asian nation will leave me with a well-rounded view of agricultural technology use at a global level.
Wales	Various	Sharing preliminary findings with practitioners at Aquaponics Association conference and visiting Aquaponics practitioners well known for leveraging the appeal of "local" and "sustainable".
Luxembourg	October 2017	Visit aquaponics practitioners to assess scale, business models, technology use and origin and post production distribution (how are they adding value?).
Belgium	July 2017	Visit aquaponics and peri urban practitioners to assess scale, business models, technology use and origin and post production distribution.
Holland	November 2017	The north of Europe, in particular the Netherlands, can be seen as the technology hub for Controlled Environment agriculture and urban farming, heavily exporting tehnological solutions/equipment to most parts of the world. There are also many examples of urban farms operating successful and others less so - Customer base and perceptions - Automation, what they think is lacking in current offerings
Czech Republic	July 2018	Assessing the technological readiness level of vision-based automation and how to increase the industrial impact of academic research, deliver knowledge and develop personally from networking with high caliber peers in the computational vision area. Hosted by: Institute of complex systems Faculty of Fisheries and Water Protection
Austria	July 2018	Visiting John Kepler University [Linz] for lecture and business convention /innovation day. followed by tour of Kubator start-up centre for tech firms.
Germany	August 2018	Visit Aquaponics practitioners and technology suppliers Identified as key players during earlier European travels.

3a. Global Focus Programme (GFP)

I was also fortunate enough to be included in one of the Nuffield Farming International's Global Focus Programs. In my case this was a 6-week travel programme, covering 7 countries (Brazil, USA, Czech Republic, Poland, Ukraine, Kenya and South Africa). Visited multiple farms of all types, policy makers and government organisations, with a group of 10 other Nuffield Farming Scholars from across the globe. I found this immensely worthwhile. I benefited from exposure to a broad range of agricultural systems, in very different political and social environments, along with interacting with all the 2017 new Nuffield Farming Scholars worldwide and hearing their take on agricultural issues and impressions from farm visits.

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A UK Nuffield Farming Scholarship consists of:

(1) A briefing in London.

(2) Joining the week-long Contemporary Scholars' Conference attended by all new Nuffield Farming Scholars worldwide, location varying each year.

(3) A personal study tour of approximately 8 weeks looking in detail at the Scholar's chosen topic.

(4) A Global Focus Tour (optional) where a group of 10 Scholars from a mix of the countries where the scheme operates travel together for 7 weeks acquiring a global perspective of agriculture.

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The Nuffield Farming Scholarships scheme originated in the UK in 1947 but has since expanded to operate in Australia, New Zealand, Canada, Zimbabwe, France, Ireland, and The Netherlands. Brazil, Chile, South Africa and the USA are in the initial stages of joining the organisation.

4. Introduction to my study tour

Technology adoption in farm settings can go one of two ways: it can be beneficial or it can be detrimental. In order to benefit from a technology as a farmer it must be a useful technology, adopted at the correct time, which makes you more efficient in the areas that you or your customers care about.

> If you only take one message away from this report, it should be:
> **Technology should make your life easier and more efficient/better in the areas that you or your customers care about.**
> **If it doesn't, is it really useful and worthwhile to you today?**

In the following chapters of this report we will break down technology use and availability in agriculture, working backwards through the process from:

Farmer Adoption → Technology Development → Government Policies

Below is a quick summary of each topic:

4a. Farmer adoption: (see Chapter 5)

- Identifying what technologies are suitable for your farm, plus choosing if and when to adopt them for maximum return on investment, is no easy feat and is likely to become more important as technology development speed increases
- What are the characteristics of farmers who adopt good technology at the right time, with examples
- How to identify where you sit in respect to others in your industry when it comes to technology adoption
- With new technologies, distinguish the hype from what's commercially viable
- What to look for in a technology

4b. Technology development: (see Chapter 6)

- Farm technology to date has been mainly about mechanisation: i.e. removing the demands for physical strength and manpower on the farm. Mechanisation has in large part been responsible for the decrease in agricultural workers from 22% to 1.1% of British population between 1850-2018[1].
- Newer advancements in machine learning plus smart software and its application to agriculture get me much more excited than mechanisation, for the simple reason that mechanisation is aimed at increasing production volume and gets cheaper as the enterprise gets larger: suiting larger farms and leaving the smaller ones behind. This next generation of automation is going to be software-based and aimed at removing the mental demands of farming and producing higher

[1] "Employment in Agriculture - Our World in Data." https://ourworldindata.org/employment-in-agriculture. Accessed 8 Feb. 2019.

quality alongside volume, and both in an environmentally friendly way. Being mainly software-based, this technology is less about hardware costs and more about user base, and therefore suited for use on farms of all sizes.

- What kind of capabilities we can expect to see, plus examples of it being used in an ag setting.
- Who is involved in development and which countries are leading the way?

4c. Government policies: (see Chapter 7)

- Like it or not, government policies affect the way we farm and policies can either be enabling or detrimental to farming at large. Policy makers are likely to struggle with the pace of advancements that are on the horizon. Can we learn from other countries' successes and failures?
- Example of EMBRAPA, Brazil's "no farmer left behind" programme, leading to increases in production and broad use/adoption of environmental practices.
- Example of South Africa struggling to deal with technology use at large and its effect on agriculture.
- Technology development and promotion strategies used outside the UK

In the next chapter I shall be looking at the first aim of my study tour (Farmer Technology Adoption) in more detail.

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The title of this report is:

Technology adoption by small and medium sized agricultural businesses in the UK

A definition of such businesses is required: but it is difficult in practice to be precise.

Location, market and sector are big factors. For example 14 acres in a rural setting would be considered a large garden. But in an urban or peri-urban setting it is still viable if devoted to horticultural crops.

Size. For commodity production, the minimum acreage for that commodity to be profitable in a one-man band is the yardstick for a small farm. Say 500 acres for arable or 250 cows for dairy.

People. A small or medium farm is one where the owner is actively involved in daily tasks on the farm.

Financial. Farms with only a few acres can sometimes be more profitable than those with a few hundred, so it's an unreliable definition. Small and medium farms, however, tend to generate enough income to support a farming family but generally won't support the income for roles that aren't directly active in production. E.g. office managers dedicated to specific activities on the farm.

5. Farmer technology adoption

Some technology can have a wonderful effect. Other technology can be a waste of time. But just as important as the technology itself is the timing of when you adopt a technology.

The mechanisms used in farming technology are becoming increasingly complex year on year. However, the mechanisms behind how to choose what technology to invest in, when to adopt it and how to avoid making costly mistakes are relatively simple and should be somewhat future proof.

Not Everyone Benefits

The financial rewards of technology adoption are reaped by those who adopt a good technology early before it becomes industry norm.

This chapter is aimed at:

- Discussing the traits of farmers using technology to their benefit, with examples
- Presenting some basic tools to assess where you sit now with technology adoption
- Methodology useful for choosing good technology
- Identifying what a technology can really deliver, is it over hyped, or under hyped.

5a. Case study: a good example of technology management

Farm: La micro-ferme du Ponceret
Translation: The micro farm Pinceret
Location: Belgium
Income streams: Production, resale, agro tourism
Farm manager: Denis Morsomme

Overview: Relatively modestly-sized diverse farm, selling own fresh/raw produce, in-house processed goods and re-selling other growers' produce directly to final customers/consumers from the farm shop that is situated in the middle of the farm. Employs a mixture of high tech environmentally-controlled indoor glass house production, semi-controlled polytunnel production, and traditional outdoor growing of vegetables. Since my visit they have also started producing and selling eggs.

Figure 2: Photo used by Ponceret on their Social Media platforms – which include Facebook

La micro-ferme du Ponceret is a great example of a farmer adopting technology suitable for their situation. From their technology implementation I would place them in the innovator/early adopter bracket. Another reason I have selected La micro-ferme du Ponceret for this example is their business model does not require constant expansion for success. It is a great example of a modestly-sized prosperous farm.

For the rest of this example we'll be talking about the qualities of Denis who, with his wife, manages the farm, and discussing the decisions he makes with respect to technology adoption on the farm.

- **He networks heavily:**
  Denis and the farm management team are heavily involved with networking; he largely uses online resources to keep up to date and augments this with farm visits – but he always tries to work with the best in their field who have real-life experience. I show a picture of him below taken while he was on a farm tour in Morocco.

Figure 3: Picture of Denis, farm manager at Ponceret

When talking with Denis the knowledge gained from his travels is obvious. He knows what his competition and the industry in general are using/doing, is knowledgeable about up and coming technologies/methods, and has in mind areas of the business where these technologies/methods could be useful to his farm in a measurable and quantifiable way.

He is also strongly motivated by the urgency of climate change. "*We have a very strong feeling ….. that spreading a profitable permaculture and agroecology business model is a good way to move in the right direction".*

- **He knows what he wants to achieve:**
  La micro-ferme du Ponceret is all about the final customers: excelling at meeting the customers' needs is where they make their profit. When assessing a technology or business addition Denis has in mind how his customers will react. Technologies in his opinion need to balance out in these four areas:

  - Increase the quality
  - Decrease production costs
  - Environmentally friendly
  - Get his message across to his customers

- **He is willing to take calculated risks:**
    - Glass houses require heating during colder months to keep production volumes consistent, independent of season. The industry standard is to have a gas/lpg-based heating system as it gives the best bang per buck. However, this non renewable source of heat would not sit well with the farm's environmental ethos or company image. Instead Denis turned to biomass and invested in this technology. He chose the simplest and most low-tech design on the market.

The word "biochar" is a combination of "bio-" (from "biomass") and "char" (from "charcoal"). A biochar reactor is in essence a large wood gas stove finetuned for producing high quality biochar via pyrolysis. You put wood in the form of pellets into an airtight heating chamber and heat it up. This causes the wood to produce a flammable gas similar to lpg/methane. Some of this gas is used to heat the wood but it produces excess gas that can be used to produce electricity and heat. After this process you are left with a charcoal-like substance that has uses in animal feeds and as a soil conditioner. Most importantly to Denis this heating method has a net positive carbon footprint; that is, it reduces the C02 in the environment.

Figure 4: Photo showing Biochar, a useful by-product of heat from wood. This is what is left behind when you remove the gas from wood chip. It is a soil conditioner

Figure 5: Photo of a kiln of the type/size of unit installed by Denis on the farm. Source: https://encryptedtbn0.gstatic.com/images?q=tbn:ANd9GcSYeK2sWPhWeMsVi-RRR1VwzZjdg_0fRjf9Nimx5QP54aa3koAy

Whilst there is a lot of hype about biochar reactors being the future of renewable heat generation, I'm doubtful it will come any time soon as the economics rely on getting a reasonable price for the biochar produced. Denis is currently struggling to get a good price for the quantity of bio-char he is producing and this investment might prove to be a mistake if it was based purely on financial motivation: but the ethos behind the heating means he can pass the increase in costs on to his customers by communicating its environmental benefits.

There are many sellers of biochar production units. Denis chose to invest in a turnkey solution supplied by a reputable seller with a good history of customer service and post-sales support. He understood that a technology should not take your time and efforts away from critical farm management tasks.

- **He is proficient at cutting through the over hype:** Due to increased production volumes it is becoming industry norm to have hydroponics or soil-less production inside glass houses. Whilst the glass house at La micro-ferme du Ponceret has much of the needed hardware for soilless agriculture installed inside the greenhouse, they have stuck to using soil. Simply put, Denis feels the quality of hydroponics is questionable and it will not sit well with his customers once the overhype settles.

Figure 4: View of the indoor part of the farm taken by author from inside the farm shop

- **He knows when to go low tech:** Denis is implementing an ERP (Enterprise Resource Planning) solution to be able to track efficiently the financial situation of each part of the business. He says: "*Like any business, tracking our financial situation is crucial".*

  However, it is easy to fall into the trap of assuming high tech solutions are always the best solution. Denis always looks for what is the easiest and simplest method to achieve his goals. He provided many examples of implementing basic concepts and technologies which solved his issues.

Figure 5: Farm shop, located in the centre of the indoor farm. Photo: author's own

  La micro-ferme du Ponceret uses social media to interact and get their message of affordable quality produce to their customers. Denis knows quite a lot about organic certification QR

Code and also technology-based supply chain verification. But he has taken a much simpler approach to getting this message across to his customers once they are in the shop. See “Coloured labels” below.

- Coloured Labels
  Is it fancy or cutting edge….no, but it does work and it works well.

  If you are in the farm shop, you can buy a wide range of produce/products from lettuce to pre-made tomato soup: if you want to eat it, La micro-ferme du Ponceret probably sells it. Whilst his range of stock is impressive, I’m more impressed with his simplistic method of product labelling. Three colours of labels are shown above each product as appropriate:

  Black Label: Grown here at the farm
  Red Label: Grown close by
  White Label: Grown far away

  This product marking/verification is extremely low tech and is a good example of tweaking low-tech solutions to increase their usefulness. It works. Denis builds trust and social capital with his customers through farm tours and honesty. The labels described above are being used by his customers to assess the quality and impact of the produce in a far more powerful way than any organic or Fair Trade sticker can compete with.

5b. When to adopt a technology

> The best technology adoption is one that becomes industry norm.
> The best time to adopt it is before your competition does.

In the example above we described La micro-ferme du Ponceret as an innovator/early adopter. This sector of farmers gets the most use and financial reward from technology. They get in there and use technology to reduce production cost or add value before their competitors, and certainly long before everyone else copies and the price of the product drops to reflect the new industry norm.

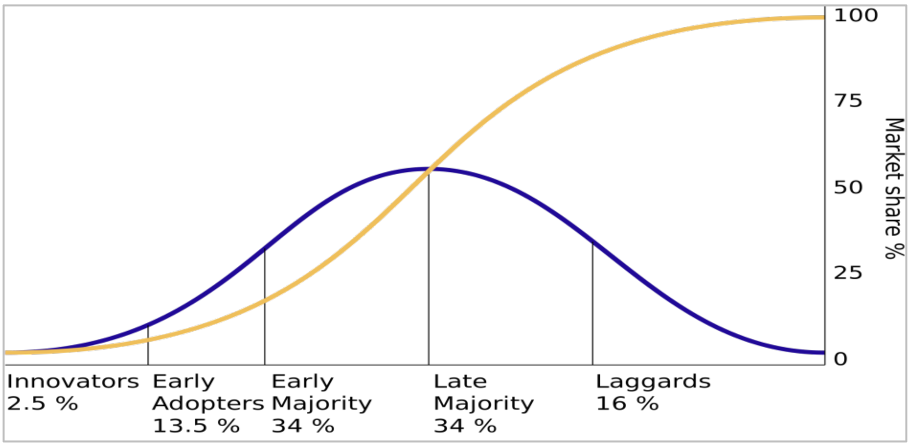

Figure 8: The Technology Adoption Cycle
Source: https://commons.m.wikimedia.org/wiki/File:Diffusion_of_ideas.svg#mw-jump-to-license

The Technology Adoption Life Cycle (see above) is an attempt at explaining the how, why and at what rate new ideas and technologies spread. The Technological Adoption Cycle is heavily related to agriculture as it was a concept conceived in 1942[2] to track the purchasing of hybrid corn seeds. The principles are:

Category	Group Name	Group characteristics
First	Innovators	Risk-orientated, with finances to try new ideas, very active with industry networking, often leading discussion groups etc
Second	Early Adopters	Often local leaders in their industry, network often with money to invest in medium reduced-risk situations
Third	Early Majority	Conservative yet open to ideas, network with others in industry frequently, will invest if risk is minimal
Fourth	Late Majority	Fairly conservative. Socially inactive with respect to industry networking
Last	Laggers	Very Conservative, lack capital and don't network with peers

You want to be the farmer/neighbour whom the locals are copying and certainly not the last one to find out about a new technology or technique in your industry. The further to the top of the chart you are the more you stand to benefit from technology, but the more risk you are taking because you are taking a gamble on an unproven technology. Not everyone is suited to being an innovator/early adopter like Denis and there is no shame in being risk-averse. However, if you're a lagger or very late adopter, this risk-aversion is severely limiting your ability to adopt technology that would increase your profit.

The biggest factor determining where you sit on this chart is not funds or capital, but how much you network and participate at large with your industry. The more you know about your competition the more competitive you can be.

5c. What technology to adopt and what to avoid

> This is a useful one that makes your life easier and makes you better in the area that you or your customers care about.
>
> Technology can bring great rewards, but it's hell when it breaks down. User-friendliness is good.

[2] "The diffusion of a culture trait in two Iowa townships - Iowa State ...." Accessed August 15, 2018. http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=17854&context=rtd.

- **Cool doesn't mean useful or profitable:**
  In a competitive industry such as agriculture it is important that we pursue advancements that increase the profitability of our farms. This does not however mean that we need really impressive machinery and technology to achieve this goal.

- **Data does not mean valuable**
  We are entering the age of internet-connected devices. It has never been cheaper to collect vast amounts of data and agriculture - like many other industries - is going to be filled with devices for measuring things that are useful. It is also going to be flooded with devices that measure non-useful things. As a farmer you know what information is useful to you and what is not, but if you're struggling with it a good thing to keep in mind is: "Can I act on this information or is it interesting to my customers"? If you can't act on it then having the data is not useful to you today.

  Using Denis again as an example, he has many sensors on his farm that allow his automation system to function or are useful to his farm management. Sensing wind speed allows him to automatically close the roof vents if the wind speed is likely to damage the glasshouse. Such sensors commonly come with a wind direction indicator as well. However, knowing the direction is not important, so he didn't invest/implement wind direction into his system.

- **Technology should be used to make your life easier**
  So you have found a technology that adds value in the areas you care about. How much of your time do you want to spend turning this data into an action?

  > "I have a dozen or so technologies that are online and useful. But I need 12 screens to see their information at the same time. Why is combining the data I paid for into one app such a problem?"
  >
  > Hugh Shedden NSch, pig farmer

  Ideally you want the data to be in a useful format that you can quickly access and act on. A million-cell Excel spreadsheet of humidity in your greenhouse is not easy to act on: but an app that shows you the current and daily min/max humidity readings is much more useable.

  Even better if you can use this information in an automated system that can act on the data and you don't even need to look at it.

  Denis chose a technology like this. His glasshouse automation keeps the temperature and humidity inside the glass house to the set points he chose, leaving him free to do other things. The only time he needs to act is if the systems texts/alerts him to say there is a problem like a power cut, or the system is unable to keep the humidity or temperature under control.

- **Technology that's going to be leapfrogged**
  As we see agricultural technology get smarter it will develop at a speed much faster than that of the mechanisation advancements we are accustomed to. Think more like mobile phone-based advancements being released every six months. For those of us adopting this smart technology there is a big risk that what we adopt will be replaced by a much better version soon after. It may be wise to seek out technology contracts that renew often, and be hesitant of those with long return on investment.

5d. What can a technology really deliver?

It's nice that one day it can do X or Y, but what is it capable of doing today is more important.
Are you fully utilising the technology you currently have, or are there small improvements that can lead to better efficiencies of existing technology on the farm?

In the example on the previous page we talked about how Denis had a clear understanding of his aims plus a set of criteria he used to assess how useful a technology is to him. But he still has to cut through the hype of a technology to really gauge what a technology can deliver to him today.

5d.i. Gartner hype cycle

When new technology or techniques emerge there are often bold claims regarding how they are set to change an industry. It can be a complex task to discern the hype from the what's commercially viable and gauge when such changes will occur in the industry, if at all. The Gartner Hype Cycle is a graphical representation of this phenomenon. It allows us to characterize the evolution/development of a technology in stages, and helps to sort the hype from the truth.

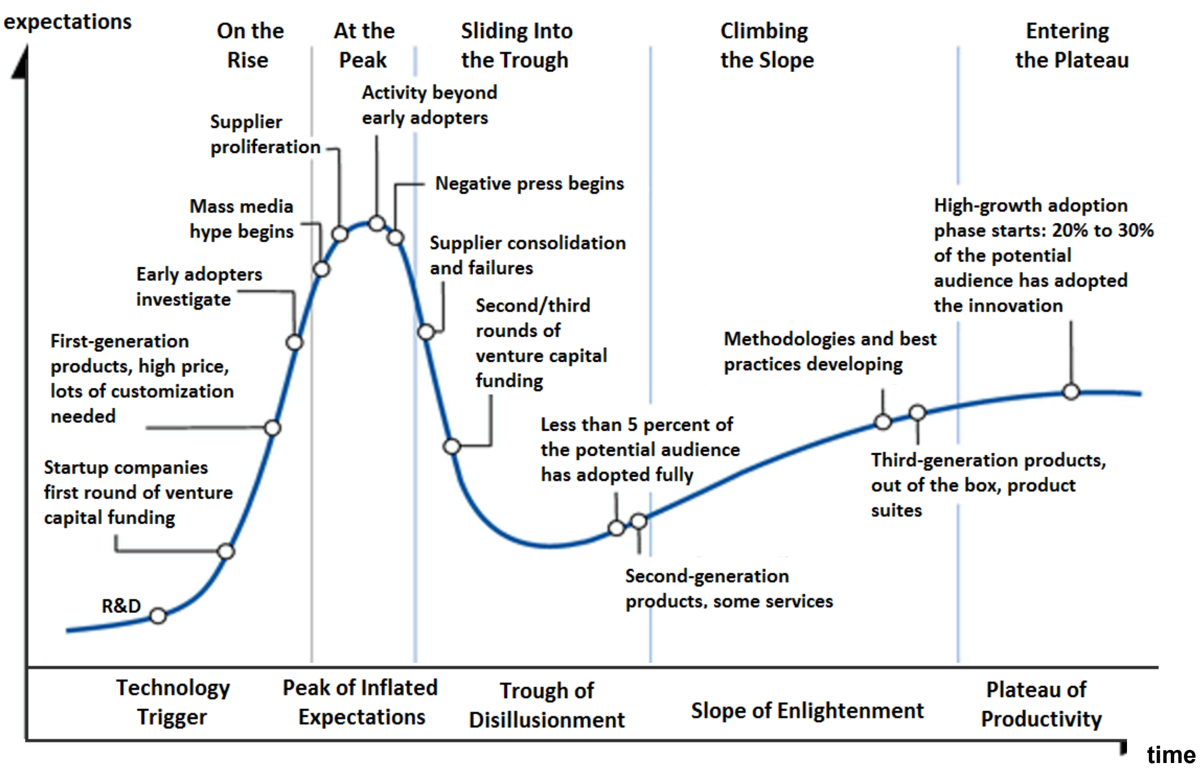

Figure 9: The Gartner hype cycle.
(Source: https://commons.wikimedia.org/wiki/File:Hype-Cycle-General.png)

When it comes to getting to the bottom of what a technology can deliver the above graph is split in two:

<u>Overhyped:</u> When a technology is on the **left of the chart**, this technology will be all over the news with claims that it's going to save the world - but you can't find any real-world farmers buying it with their own money - then the technology will be over-hyped and it won't deliver many of things that it is promising.

<u>Underhyped:</u> Initially the media overestimate the effect of a technology in the short run and underestimate the effect in the long run. The **right side of the chart** is where a technology is under-hyped. You will find farmers using it and buying it with their own money, and it can often deliver more than is promised if you know how to use it to its fullest.

5d.ii. Critically assessing claims

If you aren't adding it in the first place,
no technology can reduce your usage

When an overhyped technology is quoting statistics, appreciate they won't be comparing to your own farm: they will be comparing to a farm/situation that shows the technology in the best light.

A good example is hydroponics. Hydroponics is often quoted as reducing water usage in agriculture by 80+%.

This is only true if you are 100% irrigating your crop from communal water in a covered area. If your crop is out in the field being watered by the lovely British weather without irrigation, then hydroponics cannot reduce your water usage because you aren't utilising the target commodity in the first place. Taking Denis as an example again, his glasshouse is using soil, but reducing water usage is not a major concern because the water collected from his glasshouse gutters is more than ample for his watering needs and can fully support growing in soil.

Many technologies will claim to reduce/increase X by a substantial amount. These will often be in comparison to the worst case scenario. You need to be comparing them to your current usage and efficiencies on your farm for a truer picture of the benefits it can offer you.

Technology is no use if we are not using it. How easy a technology is to set up, use and maintain can also be overhyped. What support does the technology come with and can it be operated by someone with an hour's training - or a month's training?

The opposite of overhype is underhype. This is a technology that has been around for a long time and most farms have it. Older technology can often be overlooked and underutilised. Denis has many examples of taking an older technology and tweaking it to make it easier, simpler and more effective; from using basic labels with colour representing quality/trust, to making changes to the poly tunnel sides for better air movement and temperature control.

continued on next page

5e. Getting unbiased views

Your fellow farmers are the best people to ask for impartial advice about a technology, in particular those with no skin in the game so to speak. Visiting other farmers allows you to be aware of newer technologies, see them in person and get real-world feedback from a fellow farmer.

Using Denis again as an example, as well as thorough research online he often travels to farms, both close by and far afield, to network. When talking with Denis the knowledge gained from his travels comes out. He knows what his competition and the industry in general are using/doing, is knowledgeable about up and coming technologies/methods, and has in mind areas of the business where these technologies/methods could be useful to his farm in a measurable and quantifiable way.

Not all farmers or technology users are going to be honest about the technology they are using, especially if they have received it for free as part of a government-funded scheme or heavily discounted in exchange for promoting the piece of technology. Whilst this may seem like a pessimistic outlook, I personally always ask the following two questions when visiting farms to look at ag tech:

Did you buy it with your own money?

Do you have any skin in the game?

Once we know if there are any major bias issues then we can ask more questions such as:

Would you recommend this technology?

What were you using before?

Would you recommend the same supplier?

What would you change?

Has it broken down?

Who do you get to maintain it?

How has it made your life easier?

Did it deliver everything it claimed?

5f. Discussions

5f.i. Unjust promotions

In the tech world it is a common practice for companies to pay influential people in an industry to review a product and recommend it to people - even if it is garbage. As we see more tech companies entering agriculture will they be bringing their sales tactics with them? Getting through the wild claims about a technology to know what it really is capable of doing is already a hard task without funding trusted people in agriculture to fuel this overhype. Over the course of my Nuffield Farming study tour travels I visited many farms that were nothing more than well-funded, technology-supplier showcases masquerading as farms to promote their technology.

Would introducing laws about paid promotions needing transparency and clearly making it known that they - the person you're listening to - is financially motivated to promote the technology he is discussing hinder the growth of the technology industry in agriculture?

Should industry representatives be doing more to ensure the farmers in their industry have access to unbiased information and quick calculators to compare a farmer's current benchmarking against realistic benchmarking if they were to adopt a certain technology along with a list of trusted suppliers?

5f.ii. Changes outside of agriculture

Developments in distribution and transport networks are likely to change the price, quality and options available for British consumers as we enter into a truly global market. This will also present the opportunity to sell British products in new locations.

Are British farmers ready for this change and if so which ones? I prefer local production for local people but initiatives like the Belt and Road* mean we can get fresh British produce into Asia in a relatively cost- and time-effective way. Could small farms in the UK benefit from selling high quality produce into international markets and, if so, what would we need to make it happen?

*an ambitious programme developed by the Chinese government to connect Asia with Africa and Europe via land and maritime networks along six corridors with the aim of improving regional integration, increasing trade and stimulating economic growth. (https://www.ebrd.com/what-we-do/belt-and-road/overview.html)

5f.iii. Reaching the "Laggers" of our industry

It is those who adopt a technology early who reap the rewards of technology in farming. As we discussed earlier, it is those who network and engage with the industry, and who know what their competitors are doing, who are competitive.

Whilst the majority of British farmers are excelling, its image is based on those lagging behind: that is, we are only ever judged by our worst farmer never our best, would removing subsidies and support for those laggers be an acceptable approach - or should we increase support and lift them up? Either way it is my opinion that we either need to force them out or raise their standards.

How can we ensure that all farms are progressing, networking and using technology to benefit their farm as opposed to being in the dark and playing catch-up?

5f.iv. Will leapfrogging become a big issue?

As food production becomes more globally connected and the development of technological advancements increases in speed and capabilities, I wonder if leapfrogging of technologies by practitioners in developing nations will leave previously early adopters in developed nations bogged down by infrastructure changes and payments for previously advanced automation that is now old technology?

5g. Chapter 5 "take-home" messages

1. Cool does not mean useful, data does not mean valuable, technology should be used to make your life easier as a farmer. Look for technologies that are progressive, practical and profitable. Be aware, know what you want.

2. In order to benefit, you need to know what technologies are available: a way to cut through the overhype to know if a technology meets your needs and when to adopt it for maximum return.

3. If you are late to adopt technology in your industry then you won't be making money from your investment. Instead you are likely playing catch-up to keep production costs in line with industry norm. The best technology is one that becomes industry norm; the best time to adopt it is before your competition.

4. Network, Network, Network. Networking is key to knowing what technologies will put you ahead in your industry. Understand if you are leading or playing catch up and offer opportunities for getting real-world feedback about a technology from other farmers.

5. Know what is important to you and your farm: does the technology deliver tangible benefits in these areas? Data for data's sake is not necessarily useful, it is only useful if you can act on this data. If it is useful data is it presented in a practical, easy to understand and use way?

6. Technology doesn't need to be amazing or novel to be useful. Are you fully utilising the existing technology on your farm? Smaller advancements in utilisation could lead to large gains.

7. Be aware of leapfrogging. Technological advancements are likely to develop rapidly. Be cautious of investing in novel technology with long term return on investment.

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In this chapter we have dealt with Technology Adoption by farmers.

In the next chapter, Chapter 6, I discuss Technology Development.

6. Technology development

In this chapter we will be discussing the who, what and when of the technology development stage: plus examples of these technologies making it into agriculture: what's in-the-pipeline: and do they meet our needs as farmers?

The aim of this chapter is:

- To discuss the capabilities we can expect to see from technology currently found in research labs.
- To give examples of such technology reaching farmers who are early adopters.
- To see who is involved in development and which countries are leading the way?

6a. A good example of research

Institute: Faculty of Fisheries and Protection of Waters, Institute of complex systems
Sector: Aquaculture Research
Location: Czech Republic
Income streams: Government Funded
Staff number: 24

Overview: This is a research centre to support the Czech aquaculture industry. Relatively small centre considering the size of the Czech aquaculture industry, but very effective at meeting the needs of the industry:

- Transferring innovation into practice (technological solutions)
- Research services
- Popularisation of the aquaculture sector
- Training of aquaculture practitioners

The reason I have chosen this centre as an example is because, at a global level in the aquaculture industry, they are held in the highest regard and excel at producing industry impact whilst also producing great work in the academic community. The work they are doing on computational vision is world-leading and another great reason I wanted to visit them.

I would like to thank Jan Urban the department manager as it was he who invited me to visit the centre and kindly arranged a prolonged month-long stay including accommodation to fully understand what makes the centre tick.

- **<u>They Interact with farmers:</u>**
  If I had to put the success of this department down to one thing, it would be their in-depth understanding of the industry and its practitioners. The research staff spend a lot of time with the farmers to fully understand their needs before developing solutions, similar to the mentality of: measure twice, cut once.

- **<u>They produce useful technology quickly:</u>**
  The mentality of the department is industry-orientated. They understand the needs of the industry and this shows in their work, and they have made massive impact from picking the low hanging fruit of solutions. I visited many research centres around the world and asked all of them for a time frame and budget to develop a particular technological solution to measure the number of insects stuck to a fly paper, using computational vision. Most of the replies suggested 4+ years, and didn't ask many questions. This was the first centre to ask me reasonable follow-up questions such as:

  - "Is it useful to the industry?"
  - "How are they doing it now?"
  - "How accurate does it need to be?

  The last question had a dramatic effect on the development time of the project. Where many researchers would assume a needed academic standard accuracy of 99.6%, I only needed to be better than the current method of a human counting them with a magnifying glass – so an accuracy of around 70% would suffice. To get 99.6% would take a minimum of 4 years: the 70% would take a matter of weeks/months.

- **<u>They understand that technology availability is only part of the solution:</u>**
  Alongside developing technological solutions for the aquaculture industry in the Czech Republic the university also builds the capacity of the practitioners and managers in the industry. Whilst I was there Jan personally delivered lectures on statistics to farm managers and owners and, more importantly, how to translate the data generated in the business from just numbers to useful and actionable information.

- **<u>They also engage with the academic side of research</u>**:
  When it comes to delivering technology for the aquaculture industry the centre chooses the simplest solution that can solve the problem. But they also carry out pure academic work that will pave the way for future solutions in the industry, with world leading research on computational vision coming from the centre.

  They also have plans to make a big impact on what and how academic research is shared. Academic publications often only publish the theory and the methodology to their research and lack the ability to share the vast amounts of trained datasets used in their research and experiments. The Centre understands the importance of this data being publicly shared and are making progress towards opening a platform/site to accommodate this sharing. Speaking as a person working in the technology side of agriculture, access to these datasets would be of immense usefulness when building upon academic work to create technology solutions in agriculture.

6b. Who is developing the technology?

New technology for use in agriculture generally starts in one of three places:

- Transferable technology developed for other industries
- In academic and research centres such as the one talked about in the previous sub chapter

- Technology-based businesses that see a profitable future in smart agriculture.

- **Transferable technologies:**
  It is not uncommon for technological innovation in other industries to pave the way for advancements in agricultural technology. Much of the early research and development of the science behind computational vision and AI started in other industries. If you are an innovator in agriculture, you will find a wide range of transferable techniques and methodology used in other industries that can be used in a farm setting to increase productivity and efficiency.

  By looking at industries that use similar technologies - or have similar problems with tighter regulation - we can often gauge in what direction a technology is heading. For example, the legislation for car headlight power is based on input power being at maximum 50-watts. This means that car manufacturers have got to increase efficiency of lights if they want brighter headlights on their cars because the input power is limited by legislation. Because of this regulation the lighting used in car headlights has predicted the lights we use in controlled agriculture. In agriculture the pinnacle of efficient lighting is currently LED lighting, but with car manufacturers moving towards laser diode-based lighting, LED grow lights could soon be old technology.

- **Industry specific technology:**
  Research centres like the Czech Faculty of Fisheries and Protection of Waters discussed above are the birthplace of many technologies that are likely to bring big changes in agriculture. Other centres exist - like EMPRAPA of Brazil, which we will be discussing in the next section.

- **Technology-based businesses:**
  We are seeing Google, Microsoft and other tech giants with the expertise and resources moving into the smart ag tech sector.

6c. What kind of technology is being developed?

There is a host of up and coming technologies for agriculture, a lot of which are mind blowing. One such genera of technologies that I am interested in and hold great hopes for is Computational Vision. Computational vision is the art/method of getting a computer to understand the world that it is seeing from a camera feed or recording.

- **What is it capable of doing?**
  A camera coupled to a computer is capable of running 24 hours a day, 365 days a year, looking for the most extraordinary things, or very mundane but useful things, in the view it has from the camera lens. Programmed to measure and track the right things in an agricultural setting, it can provide information to a farmer that is not visible to the naked eye, or provide a detailed log of useful information that is too time-consuming to collect in person.

  This is one of the technologies that is bringing big changes in precision agriculture and bringing AI-based expertise and knowledge into the farm setting. This is, in my opinion, going to be a great resource for smaller farmers who cannot access the expertise of an agronomist or other specialist experts on a daily basis like larger farming enterprises can.

- **Things it can see that humans cannot**
  A camera can see very subtle changes in colour, and view spectrums of light that our eyes filter out. It can view things that are just not possible by the naked human eye. With the suitable software it is possible for even a cheap $20 computer and $2 camera combination to measure a whole host of useful things in agriculture.

  Example 1: Every time an animal's heart beats it sends a burst of red oxygenated blood around its body to replace the blue blood that has been depleted of oxygen. The camera can identify animals in its view and see this subtle change in skin colour and calculate the heart rate of multiple animals in the camera's view by the rate of these red pulses. It can also see minute movements relating to breathing. This breathing and heart rate information is useful to identify animal health issues long before more human-visible symptoms are visible.

  Example 2: Early plant tissue damage shows up near infrared light. Humans cannot see this spectrum of light but many cameras can. This means computational vision is capable of identifying and alerting farmers to plant damage from pests and diseases far before even a well-trained agronomist.

  Example 3: The research centre already mentioned in the Czech republic is working on many systems for use in aquaculture: identifying individual fish by their eye/iris; measuring growth and estimating weight of identified fish; monitoring feeding of individual fish and getting live feed conversion ratios at a per fish basis; alerting farm manager to unwell fish or presence of pollutants based on their movement in the water.

- **Less amazing but useful**
  Although computational vision can see things that humans cannot, because the technology runs 24 hours a day it can also be used to constantly measure and assess useful things that we as farmers can see in person but have limited time to monitor, and then alert us to any immediate issues in real time.

  Example 1: You will often find yourself watching and observing the animals under your care for signs that there is a problem that needs addressing - such as unusual joint movement, limping or signs of stress. This is a task that is carried out periodically as opposed to constantly because farmers need to attend to multiple tasks plus take rest and sleep. The camera can also see these changes in behaviour and movement and alert you instantly whilst also inferring the underlying issue causing the strange movement.

  Example 2: By manually taking random measurement of the plants in the glasshouse a farmer can make a prediction of the yield to expect. A camera can also measure the yield of plants in its view and identify individual plants that are not performing well.

6d. When will I get it?

This is a very hard question to answer. Some of you early adopters and innovators may already have some computational vision-based technology/automation on your farm. I have seen this technology being used in farm settings at many locations for tasks ranging from the sorting of apples based on size and colour to the tailoring of feed compositions on a per-pig basis in a pig production unit, adjusting the feed for each pig dependent on its needs.

6e. Discussions

The next big thing in agriculture is always 20 years away: that is, it takes a technology around twenty years to go from academia to industry use. Can we shorten this gap and have it tomorrow?

Can we further increase research impact by including practitioners and industry representatives in the grant/funding decisions?

6e.i. Disconnect between academic progress and Industry needs

Progress in academics is underpinned heavily by the publication of peer-reviewed articles in academic journals; these papers generally need to be novel to obtain publication. Farmers' needs are not often novel: we need solutions that increase profitability, productivity and increase the good effects we have on the land we are farming.

Before conducting research do the researchers fully understand the problems and needs of the farmers who are supposed to benefit from the research. If not, how can we as farmers better convey our needs to these researchers?

Are the needs of farmers pushed aside by research centres whose income and standing in academic circles are based on academic publications and hence novelty? If this is the case, how can we ensure that industry impact is valued as much as academic impact to produce results today - by picking the low hanging fruit whilst still paving the way for tomorrow's solutions?

6e.ii. Twenty-year cycle for innovation

In agriculture we have issues that need to be solved today, and much of the technology and knowhow in academia could go a long way to solving many of them. Basic aspects of computational vision and automation are ready for use in the agricultural sector but are struggling to make the leap out of academia. Generally speaking, it takes 20 years for a technology to go from initial academic research to industry use.

This stagnation of a technology in the stage between academia and commercialisation is a big bottleneck in technology development and adoption. Increasing funding either side of the bottleneck will have little to no industry-wide effect. What is causing this issue and what steps can we put into place to remove it? For example, by sharing data sets along with publications.

Many researchers are striving for perfect solutions with an accuracy of 99.6% or above. To get perfection takes a long time. Should we instead significantly reduce development time by aiming for more realistic accuracies that beat the methods what we are using now?

6e.iii. Farmer-ready technology

Computational vision and other such computer powered automation can produce vast amounts of valuable data to a farmer, but to be useful it has to be used.

In the funding of agricultural technology development, the emphasis should be placed on ensuring that the resulting technology produces valuable data for the farmer, conveyed in a way that the farmer can easily act on the data.

If we want technology that solves our problems as farmers, we should have input in the earlier stages of the technology development. Would pushing for industry representatives to take an active role in lobbying and conveying our needs and problems to those granting funding and conducting research on agricultural issues, solve these problems?

The pricing/cost of software-based solutions should theoretically be affordable to farmers of all sizes as the primary cost of software development is minimal when spread across a large user base. However, just because it's cheap to produce doesn't mean that it will be offered at an affordable price. Is it not possible for tech companies to price their product so that it is economically viable for small farmers without damaging the tech industry's overall profitability level?

6f. Chapter 6 "take-home" messages

1. New technology is aimed at removing the thinking demands of farming (ie precision agriculture). Just as you are unlikely to outlift a tractor, it's unlikely that we will out-think this automation (at its specific task).

2. Computational Vision (C-V) is particularly promising, as it is the art of enabling a computer to understand what it is seeing in a camera feed. C-V does not need to sleep, it does not need to blink, and it is able to see things that the human eye cannot. For example, the heartbeat of an animal.

3. If you are an early adopter/innovator look for technology in other industries that is transferable. In particular look at those industries with tighter regulations or higher competitive or profitable aspects. These industries often pave the way for transferable technology.

4. A large sum of money is being granted for research into solutions to agricultural problem. By better conveying our needs and problems to these funding organisations and researchers we should ensure that this funding is being well spent and leading to useful solutions

5. There is a bottleneck in technology development which is slowing down academic research and the commercialisation of academic research on the subject of AI and computational vision. Academic publications share the theory and methodology but seldom share the datasets they built to produce the work, so this data has to be manually reproduced - again at great cost by other academics and companies further developing the research to be industry-ready. We should be openly sharing these valuable datasets if funding comes from public sources.

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This chapter has been about Technology Development. Finally we shall discuss Technology and how it is affected by Government policy.

7. Policy and technology

Like it or not, government policies affect the way we farm and policies can either be enabling or detrimental to farming at large. **This section is aimed at:**

Discussing good examples of government organisations promoting the development and adoption of useful agricultural technologies. What mechanisms are used in each step.

Presenting some less-than-ideal government policies that have negatively affected agriculture.

7a. EMBRAPA: No Farmer Left Behind

Type: Government Organisation
Sector: Brazilian Agricultural Research Corporation
Location: 46 Centers across Brazil
Income streams: Government Funded
Staff number: 9,790 (2,444 researchers)

Overview: The Brazilian Agricultural Research Corporation concentrates on agriculture-related research and development and, just as importantly, technology transfer to the farmers it was made for.

The reason I have chosen Embrapa as an example is because they have in my opinion excelled in key areas of agricultural technology development:

- Increased production
- In an environment-enriching way
- Promoted useful technology that meets farmers' needs
- Without leaving the smaller farms behind
- Supports its farmers thru the complete technology process: Development>Awareness>Adoption

Here are some key aspects of Embrapa:

- **<u>They create useful technology</u>**
  Embrapa research centres are great places to visit: busy places, well staffed with field trials happening all over the country. Whilst it's possible that some of its 9,000+ staff are working on high-tech solutions, I saw many of the staff working on simple solutions for farming problems. Essentially they have been picking the low hanging fruit by developing easy-to-implement and easy-to-understand management practices and technologies.

  By ensuring that farmers have access to specialists to guide them through soil management, they are building capacity in the soil, leading to greater yields and, in the long term, increased stability in year-to-year production volumes due to increasing soil organic matter.

- **<u>They engage with farmers small and large</u>**

Embrapa staff interact with farmers to fully understand their issues and develop technology that meets their needs. Embrapa employ many different mechanisms for farmer interaction:

Regional Farmer-to-Farmer (peer to peer) groups
Specialist/consultant to farmer groups
Online tools and help, interacting via social media etc

Developing good technology for farming is only part of the solution. In order for it to be useful it needs to be used by the farmer in his field/farm. The mechanisms in place to ensure that technology adoption is quick and simple are:

- Show a group of leading farmers from a region in person a side-by-side comparison of the benefits of adopting a technique/technology.
- Show them what you did and how to do it for themselves if they believe the benefits to be worthwhile.
- Support these local industry leaders to host other local farmers on their farm and repeat the above steps.

- **<u>More than just increasing production</u>**
  When developing a technology they aim for solutions that increase production volume/quality, whilst enriching the environment they are implemented in.

Figure10: Photos giving examples of issues/concepts Embrapa are tackling.
Source: https://www.embrapa.br/en/international

I was particularly interested in their research motivation and aims around forest/livestock integration. It was relatively simple. Instead of having animals in a pure grass pasture, they are instead put into a pasture that has been planted with trees spaced widely enough apart that the tree canopy does not hinder the growth of the grass below.

The motivation/aims:

- Identify the optimal tree spacing for animal production
- Increase/diversify income streams to include meat and wood sales
- Decrease annual volatility in grass growth caused by weather events
- Increase the biodiversity of animal production system
- Store carbon in and build capacity of pasture soil

Again this is a basic technology that any farmer could adopt and use. At the research centre there is a side-by-side pasture for comparison so farmers can see with their own eyes. Here is what we did, here are the results and this is how you do it, if you need help just ask.

7b. Brazil's chaotic policy changes

In August of 2018 a Brazilian federal judge ruled that glyphosate weed killer could no longer be legally imported into Brazil. There was a 30-day period for this change to come into effect pending investigation into its health issues.

Whilst this policy reform was later revoked/cancelled it caused uproar and chaos in Brazil's agricultural community. This weedkiller was a risk-mitigation tool for farmers small and large to remove the uncertainty and crop losses associated with weeds. Whilst I generally agree with the banning and reduction of chemicals in agriculture, bringing in overnight policies with an unmanageable grace period leaves farm owners and managers without time to acquire and implement alternative risk management protocols and solutions.

Many of the farmers I talked to regarding this policy reform were confident that it would damage their businesses and potentially lead to severe financial issues as it left them without time to mitigate or deal with the risk of weeds affecting production.

7c. South Africa limiting technology use

Currently the primary motivation for technology adoption is to reduce production costs or remove reliance on a labour force to continue production. As technology is advancing the primary driver becomes more about what the automation can do that no human could achieve.

The effects of automation and mechanisation on all industries are going to bring about social and political challenges regarding employment. With the increasing pressure we are facing from job loss and automation, policy makers and governments around the globe are likely to introduce policies and campaigns to slow the effects of what some are calling "the Fourth Industrial Revolution".

I saw a local council/government version of this in South Africa when visiting a high tech automation line with no human labour. It used vision-based automation to check apples for parasites/damage. removing security issues. Later the apples were automatically sorted by colour and size into batches for packing. At the end of one of the best/latest automated produce sorting line was a human-powered packaging line comprising around 40 workers packing the apples into crates - because a packaging machine does not offer sufficient benefit over human operators. The plant manager summarised the political pressure he was facing as: "*If you want a permit to automate, it has to be doing something that a human cannot*".

7d. Discussions

7d.i. Long term policies

Farmers as business people need stability in the policies that govern them, and changes should be introduced in a timely fashion with adequate warning so that risk mitigation and business plans can be adapted.

Will UK policy makers buckle just as Brazil did and introduce changes quickly in reaction to public pressure? Is the recent overnight reform of the general licence for pest management in the UK an indicator that our government is unable to deal with public pressure?

With public perception of agriculture often not being up to date or factual, how will we as an industry ensure that our policy makers introduce policy reforms in a timely fashion that help the industry move forward?

As technology reduces the man hours per tonne of produce, I expect to see the number of people working in the agricultural sector drop. Will we have reactive and chaotic policy reforms around this issue - or long-term visions and policies that farmers can build a robust business plan around?

7d.ii. Supporting the whole technology cycle

The British government has done a great job of financially supporting technology adoption by British farmers via subsidies and low interest loans for farm-related technology, especially those that increase environmental aspects. Funding for cutting edge research has also brought about the development of promising technology for British agriculture.

We are heavily funding each stage of the technology cycle but are getting little return on investment or industry-wide impact. Is this because we aren't seeing the full picture and allowing bottlenecks in what is a cycle to limit progress? If so, can we remove these bottlenecks by increasing collaboration and interaction between all involved in the cycle?

We are funding research for agriculture to be carried out by individuals who sometimes have never personally met a farmer or set foot on a farm themselves. Should we as farmers take more responsibility regarding this and interact more with those receiving funding to solve our issues and in doing so remove the information bottleneck between user and developer? If so, how?

7d.iii. Will leapfrogging become a big issue

Digital technologies that are already starting to penetrate into the agricultural world are based on smart software and not hardware. Software tends to develop much more quickly than hardware.

As food production becomes more globally connected and the development of technological advancements increases in speed and capabilities I wonder if leapfrogging of technologies by practitioners in developing nations will leave previously early adopters in developed nations bogged down by infrastructure changes and payments for previously advanced automation that is now old and obsolete technology?

7e. Chapter 7 "take-home" messages

1. The only thing worse than a bad agricultural policy, is an agricultural policy introduced with no warning or time frame that would have allowed farming businesses to plan ahead for the changes. We need stable and long-term goals to meet the needs of the planet, farmers and the general public.

2. Policy makers are likely to struggle with the pace of technological advancements that are on the horizon and equally unequipped to deal with the speed at which social movements can develop in the now interconnected world.

continued overleaf

3. Some countries (Brazil and South Africa for example) have already introduced agricultural policies hastily, with little to no warning, that have had a negative effect on farming businesses. Let’s learn from their mistakes.
4. It doesn't matter how good our best farmer is, we will be judged by our worst. It is important to ensure that all British farmers of all sizes are excellent, and very important that we get this message across to the general public, or our government will face pressure to over-regulate.
5. We can support technology development to the best of our ability but if it isn't getting adopted by our farmers then it is not useful. To support our farmers, ensure that the technology suits their need, that they know about it, that it is easy to see its benefits and easy to implement.
6. As discussed in Chapter 5, peer-to-peer networking is key to having constant progress in farming. Getting farmers to engage with the industry is a big part of progressive agriculture.
7. There is a lot of low hanging fruit that we are missing. Many of our issues in farming can be solved with simple solutions, but unfortunately we are favouring the funding of complex solutions.

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In the next chapter I will summarise my overall Conclusions from this amazing study tour.

8. Conclusions

The agricultural industry in the UK is doing a great job of supporting the development and adoption of technology across all its sectors. Whilst we are leading the way in certain aspects there is equally a lot of room for improvement. No country however is prepared for the changes to come from technology and we should be thinking to make agriculture resilient to these coming changes.

1. Ensuring that all our farmers network is key to ensuring we as an industry progress in general, and particularly so in respect of agricultural technology. It will remove bottlenecks and ensure that British farmers have access to, adopt and fully utilise, technology on their farms.

2. Domestic public perception of British agriculture is not reflective of the great practices of the majority of our farmers. As access to global produce becomes cheaper and easier to obtain, having the British public choosing local produce is key to resilience.

3. Basic aspects of computational vision and automation are ready for use in the agricultural sector but are being held back by a mismatch of aims between academics and practitioners. Our farmers would benefit greatly from basic solutions that are currently only found it academic institutes.

4. Currently the primary motivation for technology adoption is generally to lower production stats or remove the reliance on a labour force in order to continue production. Farming technology and automation emerging now and in the near future is aiming to replace the mental and cognitive workload of a task or entire industry, leading to solutions that could see tasks performed more cheaply and more reliably, whilst offering additional benefits of increased quality and reduced environmental impact.

5. The effects of automation and mechanisation on all industries is going to bring about social and political challenges regarding employment. Policy makers and governments around the globe are likely to introduce reactive policies and campaigns to slow the effects of what some are calling “the Fourth Industrial Revolution”.

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Recommendations, based on the information/experience gained during my study tour, are given overleaf. Each Recommendation is given in two parts: firstly the Recommendation geared for farmers and practitioners, and secondly that same Recommendation directed to government bodies and researchers.

9. Recommendations

Technology adoption and development is a cycle with many key players. There are bottlenecks in this cycle that are limiting the capabilities and speed of the whole operation. Developing one aspect of the cycle will not have any major effect on outcomes unless these bottlenecks are first removed.

1. **a. For farmers and practitioners**

   Network, Network Network: It doesn't matter if you are farming potatoes on half a hectare or beef cattle on a million, get out there and network, visit other farmers. Networking is the biggest determining factor on if you will choose the right technology and adopt it.

   b. For Government/NGOs: Promote farmer-to-farmer interaction. We (the UK) will only ever be judged by our worst farmer, never by our best. But the biggest difference between our best and our worst is how much they network. This will also speed up the rate of technology adoption in the industry.

2. **a. For farmers and practitioners**

   Know what you want: Technology should be increasing the things you care about and technology should be used to make your life easier as a farmer. If you know what is important to you it makes it much easier to assess a technology's usefulness to your farm.

   b. **Government/NGO**: We know what we want from technology in agriculture: we want solutions that increase industry profitability and productivity whilst enriching the environment. We are spending a lot of money on research for agriculture that does not match the aims and needs of farmers. Increase your efforts in academic industry knowledge transfer or we won't get useful research.

3. **a. For farmers and practitioners**

   Don't just concentrate on new technology: Big gains can come from adopting new technology, but that doesn't mean we cannot get good returns from old technology or by using existing technology better. Are you fully utilising the technology you currently have - or are there small improvements that can lead to better efficiencies? Solve problems with the simplest solution wherever possible.

   b. Government/NGO: We are favouring and funding research based on its wow factor and not its usefulness for the industry, missing a lot of lower hanging fruit in the form of basic solutions. To reduce this I recommend a portion of government grants for research being verified useful by an unbiased sector representative before funding is granted.

continued overleaf

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4. **a. For farmers and practitioners**

   If you're doing well, let it be known: Public perception will affect your farm even if you don't deal/sell directly with the general public. If you're doing good things let it be known, leverage tools such as social media because it's simple but don't forget that the most powerful tool you have is your story, and you delivering this story in person on your farm to visitors is hard to compete with.

   b. **Government/NGO**: You will be feeling pressure from the public regarding policy on agriculture and subsequently technology use in the sector. A lot of this pressure will be fueled by misinformation or outdated understandings of farming. We are making great progress in British agriculture. Ensure the public know this and we shall have a much better chance of promoting practices and policy that are proactive instead of reactive.

5. **a. For farmers and practitioners**

   Data, Data, Data: Make sure that It's useful, easy to use and that you really own it. Don't fall into the common trap of thinking all data is useful. If you hear the word Data ask the following questions:

   - Is the data useful and can I make changes based on this data?
   - If it is useful is it easy to read/interpret and use?
   - Can I merge this data with other related and useful data onto one screen?

   b. **Government/NGO:** The next generation of automation is powered by machine learning and verified big data training sets are key to development. Great work is being carried out in academic institutes and, whilst their publications summarise the overall results, the trained data sets built at the expense of the taxpayer are seldom shared. This means a lot of researchers are spending significant amounts of time manually building data sets that already exist but are not available. Access to these data sets is key to getting AI technology onto farms in my lifetime - not my grandchildren's. I recommend mandating that these data sets need to be in the public domain and easily accessible.

10. My post Nuffield Farming Scholarship work

This is what I have been doing since the completion of my study tour:

The family farm

There is something to be learned from every farm visited and humbling to know that we have lots more to learn from others before reopening the family farm for food production. I enjoyed visiting smaller peri-urban farms which thrived on meeting the local demand for high quality produce, and plan to transfer some of the things I learned to the family farm.

Redirecting AquaponicsLab

My Nuffield Farming Scholarship has been eye-opening for understanding the drivers and barriers in agricultural development. Ensuring access to technology for all is only part of the solution to leading positive change in agriculture. So I have broadened the services offered by my company - the AquaponicsLab - to include community/public engagement, conflict resolution, and am capitalising on local added value to accompany our initial offering of technological solutions.

From a clientele standpoint, we are still addressing the needs of the small to medium sized practitioners but branching out beyond glasshouse and soilless agriculture because this is where we can have the greatest impact. The technology we are offering is also up for discussion at the time of this report: we will be deciding if we take on the challenge of commercialising some of the more basic computational visio-based automation.

It also became clear through my Nuffield Farming Scholarship that competitively priced services are not all that is needed to get technology penetration into an industry. We are also discussing methods on how to get messages and technological awareness to the late adopters and laggards.

Policy Advice UKUAT

There are major changes coming to the British agricultural sector with Brexit set to be the biggest change in agricultural policy since World War II. It is imperative that we decide on policy that has the best interest of local customers, farmers and environment, embedded within its core. Policy and law changes in general usually lag behind the views of the population. This can lead to policy that does not represent the demands/needs of the population or industry. Uneven pressure from pro-agriculture or anti-agriculture groups can also lead to policy that does damage to the goals of all involved.

After consulting with other practitioners in the urban agriculture industry and representatives within Defra I am sorry to realise that our industry is not coherently represented at a government level and much can be improved to better support the urban and peri urban agricultural industry. Because of this I have joined UKUAT in a bid to better give the urban agriculture sector practitioners a voice and ensure we can collaborate to push policy makers for a post-Brexit policy that meets the needs of the industry. This will be needed as the industry grows - to add resilience and ensure the urban agriculture industry can thrive in a rapidly changing world

Academia

Since my Nuffield Farming Scholarship travels I have been working closely with universities conducting computational vision-based research to identify agricultural industry opportunities and applications for this technology.

See next page for Thanks and Acknowledgements

Thanks and Acknowledgements

Looking back over my Nuffield Farming Scholarship journey, I am amazed at the personal and professional opportunities I was presented with. The Nuffield Farming Scholarships Trust offers a very unique experience for the Scholars and over the past 18 months I have been privileged to visit and better understand the needs of small farms and urban farmers at a global level, while at the same time experiencing the inner workings of government bodies and NGOs.

Nuffield network and staff

The Scholarship provides a platform to exchange insights/ideas/knowledge with many agricultural personnel, from practitioners to policy makers. For such an opportunity I would like to firstly thank the Nuffield network and staff for delivering such a great programme. In particular I would like to name Mike Vacher, Poey Vacher, Wayne Dredge, Sally Thomson for their outstanding commitment/work in ensuring the Nuffield Farming Scholarships Trust stays on track with its mission to lead positive changes in agriculture.

Family and colleagues

I would like to thank my family, friends and colleagues for the range of help they provided and extra workload taken on to allow me the time to pursue this Scholarship: along with the bouncing of ideas and learning from the travels that ultimately made their way into this report.

Sponsors

I am grateful to the Nuffield Farming Scholarships Trust and The Richard Lawes Foundation for awarding, mentoring, connections and funding for both the GFP and the personal studies. Your support during this Scholarship has been invaluable and much appreciated.

Practitioners

Opening your farm gate to a fellow farmer for an open conversation can bring about great discussions and opportunities for sharing of knowledge, ideas and current difficulties. That being said, opening your farming operation to a stranger and showing him the good, the bad and the ugly requires a certain amount of trust and confidence. I would like to thank each and every one of you for your openness, honesty and passion about your farming business and look forward to seeing your progress over the coming years.

NGO's/Government Organisations

Along the Nuffield Farming journey I was fortunate enough to meet with and be hosted by multiple NGO's and Government Organisations. I would firstly like to thank current and previous ambassadors of the British, Irish, Australian and New Zealand governments, dotted around the globe working on agricultural issues, for taking the time to speak with me regarding the state of agriculture in specific regions. It proved to be a great starting point for directing farm visits and direction of research areas whilst travelling. I would also like to thank the numerous NGO's for their help securing farm visits and connections otherwise hard to attain in developing regions.

Academics

I am very grateful for the work of academics in general and would like to thank those institutes that opened their doors to me for discussions on technology readiness level and methodology for

increasing academic-industry impact. In particular University of South Bohemia [Institute of complex systems], Edge Hill University [Faculty of Computer Science], Harper Adams University.

Mentors

Technology in general is advancing rapidly and as such it is challenging to keep up to date with the developments within each sub industry and understand the importance of certain advancements and limitations of technologies. For this I was fortunate to have multiple mentors whom I believe I should name for their time and kindness in developing my knowledge in those areas: Jan Urban, Paulo Marini, Egor Zindy, Antonin Barta.

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May 2019

978-1-912059-78-2

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Published by Nuffield Farming Scholarships Trust
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