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ESG
Global | Thematic research

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Smart farming world

Enabling sustainable growth

- **As global populations rise, feeding the world won't be the only issue on the mind of society, companies and investors**
- **There is a need to address the negative impact from crops and livestock in agriculture, such as emissions and other ESG factors**
- **Smarter farming technologies, from robotics to big data, and synbio to genetics, can help feed the world more sustainably**

Why read this report?

Smarter farming to feed the world sustainably

Population growth, environment and labour issues in food production…

Food, glorious food! Despite global population growth set to be lower in a post pandemic age, we believe that this factor alone may not be sufficient in alleviating the pressure to feed world sustainably. For example, the negative issues of climate change, environmental and labour factors from agriculture are increasingly at the top of the mind of society, companies and investors.

By 2050, we expect the global population to hit 8.5bn. The UN expects each person to consume 12% more than they did at the turn of the century. We believe this implies that total food consumption may grow by 60% at the midpoint of the century.

In this report, we outline key data point observations, issues and pressure points for feeding the world sustainably. This includes global population growth dynamics, food demand as well as environmental and labour issues. This sets up the thematic motivation for the report and then we move on to look at how various smart farming tools are being used today in making agriculture more sustainable in the longer run.

Understanding smarter farming applications today

What is smart farming? Smart farming naturally includes technologies such as robotics and connectivity, often using Internet-of-Things to track and automate activity on farms. But in the modern day, farms are also starting to use big data, artificial intelligence, drones and blockchains to process and make sense of activity in real-time. However, as the farm becomes smarter, allowing the production of crops, feeds and livestock to increase yields, reduce water use, energy and labour, this digitisation also brings issues of cybersecurity and hacking.

We believe there is value in understanding smart farming beyond the traditional definitions of simply pure digitisation. So we look at how innovations such as vertical farming, hydroponics, alternative protein for human consumption, synthetic biology and animal protein/pain killers can help with reducing water use, emissions and improving ethics in the modern agriculture setting. We also look at the regulations landscape globally to support smarter and sustainable farming.

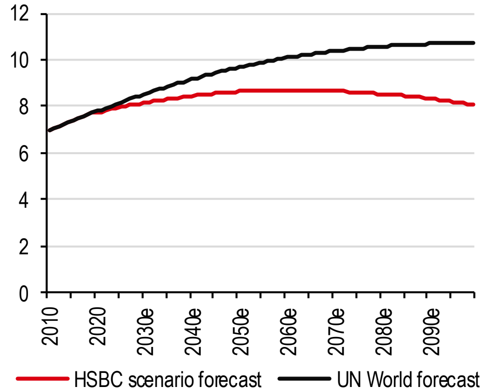
Did you know?

- Global population set to rise to 8.5bn and world set to consume 60% more food by 2050
- Food related GHG emissions are responsible for 26% of global emissions
- Global AgTech to grow from about USD22bn today to nearly USD140bn by 2030
- Digital farming technology increased yields up to 30% recently in trials in India
- Vertical (indoor) farming uses no soil and 95% less water than traditional methods

We also publish an accompanying report in which we highlight companies exposed to smart farming technologies and applications, entitled “Powering smart farms: Ten thematic stocks” (3 March 2022).

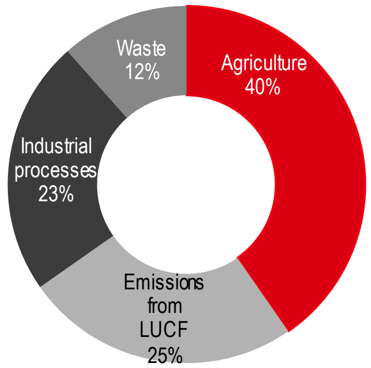
Feeding the world and smarter farming in charts

Global populations lower in post-COVID-19 world (billion)



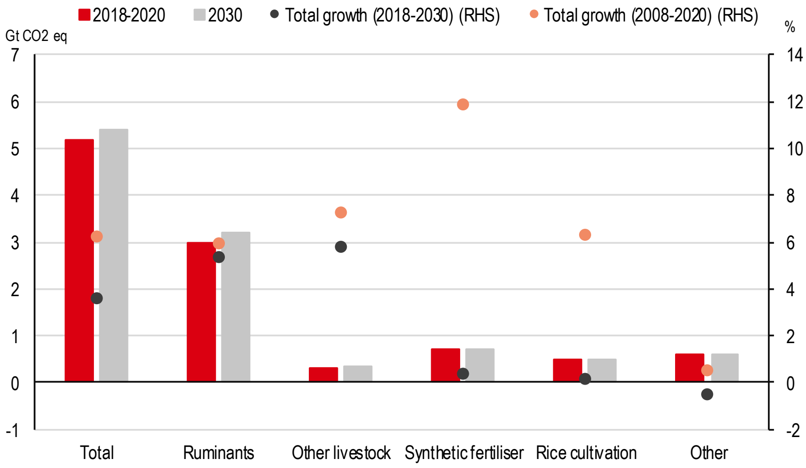
Source: HSBC estimates, UN

Agriculture is 40% of global non-energy GHG emission sources



Source: HSBC, IEA, EDGAR, Global Carbon Project, Note: LUCF is Land Use Change and Forestry. 2012

Direct GHG emissions to 2030 - from crop and livestock production (by activity)



Source: OECD FAO

Smart farming matrix: Impact on sustainability growth themes

Technology or application	Emissions	Crop yield	Land	Water	Animals	Labour	Ethics/social
Connectivity	○	●	●	●	●	●	
Robotics	○	●	●	●	●	●	●
AI, big data & data analysis	●	●	●	●	●	●	●
Drones			●			●	●
Blockchain	○		●	●	●	●	●
Cybersecurity	○	○	○	○	○	○	●
Alternative proteins	●				●		●
Synthetic biology	●	●	○				
Genetics, medicines	●	●	●	●	●		
Vertical/indoor farming	●	●	●	●		●	●
Circular economy	●		○	○	○		●

Source: HSBC
Key: ● = Direct impact, ○ = Indirect impact
Key: Connectivity framework = red, Automation = orange. Experiential = blue, Digital health = green

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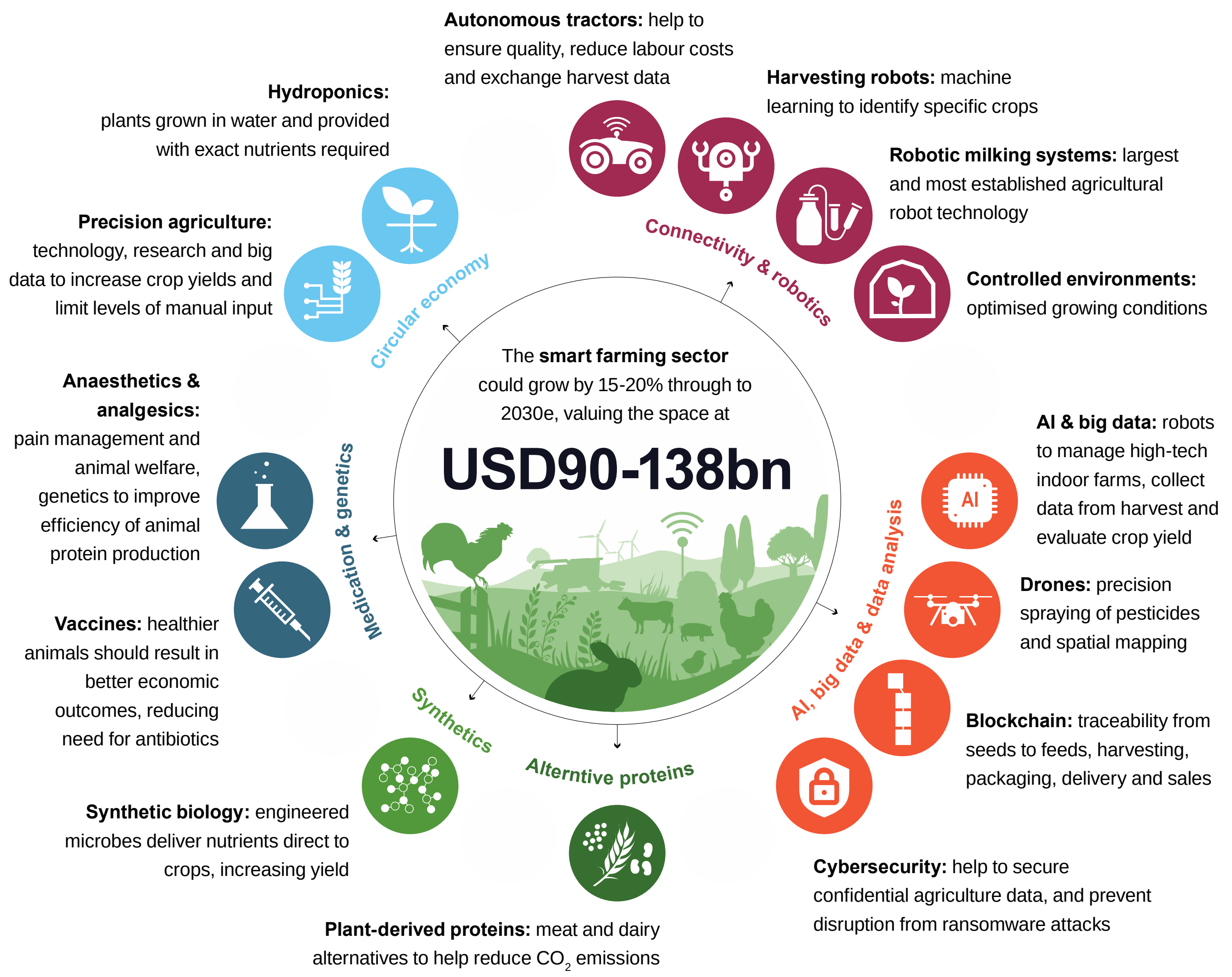
21st century smart farming

The rise of disruptive technologies …



… and their impact on sustainable growth

Technology/application	Emissions	Crop yield	Land	Water	Animals	Labour	Ethics/social
Connectivity	○	●	●	●	●	●	
Robotics	○	●	●	●	●	●	●
AI, big data & data analysis	●	●	●	●	●	●	●
Drones			●			●	●
Blockchain			●	●	●	●	●
Cybersecurity	○	○	○	○	○	○	●
Alternative proteins	●				●		●
Synthetic biology	●	●	○				
Genetics, medicines	●	●	●	●	●		
Vertical/indoor farming	●	●	●	●		●	●
Circular economy	●		○	○	○		●

Key: ● Direct impact ○ Indirect impact

Source: Finistere Ventures, HSBC

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Feeding the world

- Feeding the growing population is not the only the issue on the top of the mind of society, companies, innovators and investors
- The world is more aware of the need to provide food sustainably
- We look at pressing and often intertwined issues presented by the agricultural sector, preparing the motivation for smarter farms

> **"Please, sir, I want some more"**
>
> **Oliver Twist by Charles Dickens**

Food, glorious food!

Growth but sustainable

Feeding the population, one could argue, has always been a fundamental collective task for civilisation. This is one of the thematic strands we highlighted in our report discussing the history of centralised cities (and the future of more decentralised ones) in our think piece called "Unbundling the city: beyond urbanisation" (2 May 2017).

One of the key drivers in maintaining a society is producing enough food[1], and an urgency of this historically has been population growth. People throughout history have been concerned that population growth would outstrip supply. For illustration, this was suggested by Thomas Robert Malthus in the late 1700s, with food supplies being outstripped by population growth, thus harming growth – also known as a Malthusian catastrophe.

However, in the 21st century, we also have other concerns, in addition to worrying about feeding the world. For example, we are more aware of the strains and damage we cause to our environment from the production of food within agriculture. There's heightened awareness from society as a whole, companies, innovators and investors for the need to feed and grow the world in a more sustainable manner.

In this chapter, we take a high level observation of the current and potential future dynamics of population growth. Then we focus on a host of intertwined issues related to food production. This includes land utilisation in agriculture, the fragmented nature and size of farms globally, the allocation of production on farms, regional food nutrition trends and also the various negative impacts of agriculture - ranging from emissions, deforestation, biodiversity, fertiliser and more.

1 Distribution of food equitably is a whole separate discussion beyond the scope of this report.

Growth trends impacting agriculture

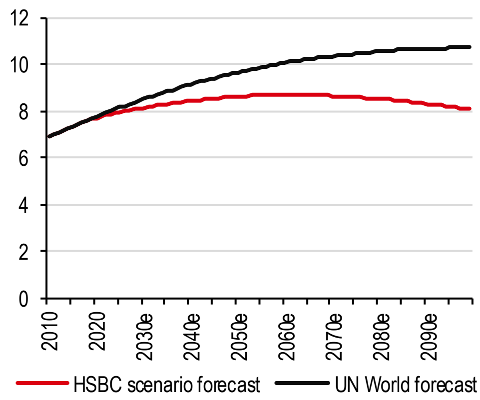
Global population to consume 60% more food by 2050…

Global populations

Before the global pandemic, the UN had projected the world population to hit approximately 10bn by 2050. However, according to one of our HSBC scenarios in a post pandemic landscape, we project that the global population will be lower, in part due to declining birth rates, and hit 8.5bn by the mid-century. While DM populations are already in decline, we expect EM populations to only peak after the 2050s. See chart 1 and 2.

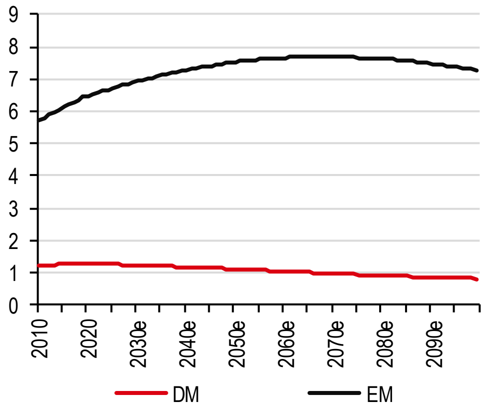
Despite the overall reduction in population expectation, in a post pandemic world, we don't believe it will necessarily ease the burden of feeding the world. The UN expects each person to consume 12% more than they did at the turn of the millennium. And we believe this implies growth of 60% in total food consumption worldwide by 2050. We expect a host of technologies and innovations to play a role to meet this growth in food demand in a sustainable way. We outline the various technologies and applications in the next chapter.

Chart 1. Global populations lower in post-COVID-19 world (billion)



Source: HSBC estimates, UN

Chart 2. EM vs. DM population (billion)



Source: HSBC estimates

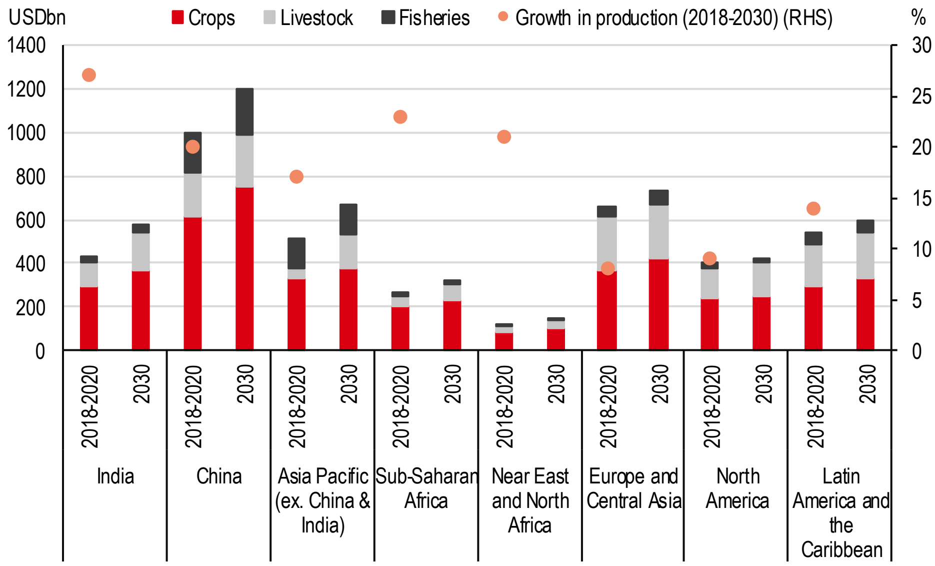
EM agriculture production set to grow the most, percentage wise…

Global agriculture

As we highlighted earlier in this chapter, we expect EM populations to grow faster than the DM. Analysis by the OECD FAO suggests it expects the growth in agriculture production over the coming decade to be higher in EM than in DM: India (27% growth in production), Sub-Saharan Africa (23%), Near East and North Africa (21%), mainland China (20%) vs. North America (9%), Europe and Central Asia (8%).

On a nominal level of production (USDbn value) of global agriculture, the dynamic is slightly different in the production of crops, livestock and fisheries by 2030: mainland China (USD1200bn), Europe and Central Asia (USD730bn), Asia Pacific (670bn), Latin America and the Caribbean (600bn), India (USD580bn), North America (USD420bn), Sub-Saharan Africa (USD325bn) and Near East and North Africa (USD150bn). One observation to note is that outside mainland China, most of the EM countries are still lower down in terms of nominal agriculture production by 2030, even though these regions are expected to have greater population growth.

Chart 3. Global agricultural production growth trends to 2030



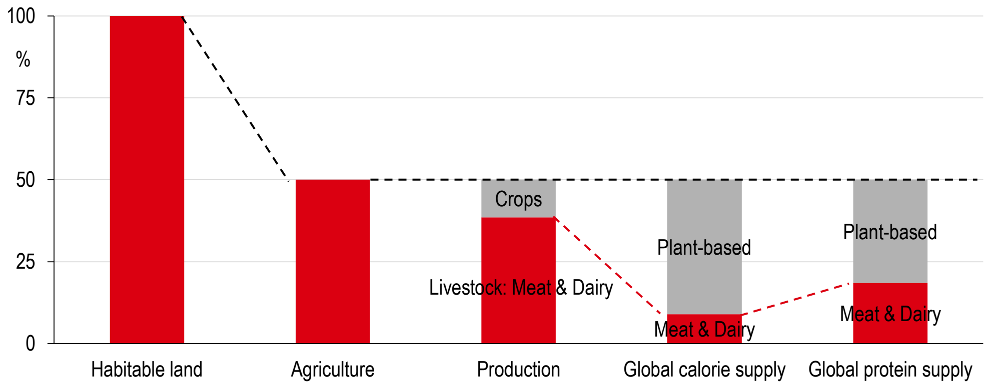
Source: OECD FAO

Land used in agriculture

There is a mismatch between land used for livestock vs crops to calories generated…

Within agriculture, like most sectors, productivity of assets is key. Within food production, better use of land means it is easier to meet the food needs of a growing population which is better for the farmers too. However, we note that not all land is equally used in this sector. For example, even though livestock uses 77% of the land, it only generates 18% of the world's calories and 37% of its proteins today. Whereas crops (e.g. plant-based) food uses 23% of agricultural land but provides 82% of the global calories and 63% of its proteins. See chart 4.

Chart 4. Global land use for food production



Source: Our World in Data 2019

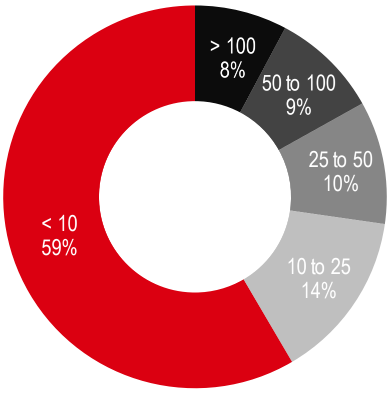
Fragmented farms

Fragmented farms mean its trickier to scale technologies

One of the reasons why generally it has been tricky to digitise farms is due to the nature of fragmentation in farms. By this we mean, many farms are so called smallholdings (small farms), and each farm's needs can vary. This means it's somewhat more complex, and perhaps trickier for companies to build systems to cater to all of them – in technology speak we call it the ability to "scale" solutions.

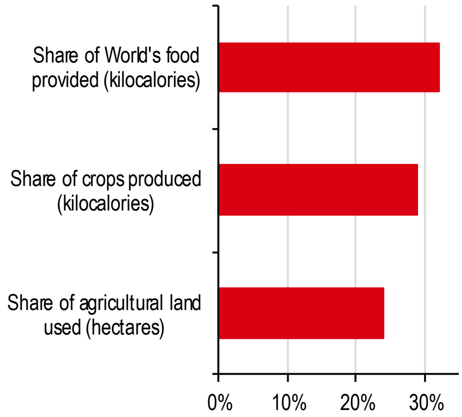
For example, Vodafone's head of IoT business development, Phil Skipper says that it doesn't focus on the agriculture business in part due to the "fragmented" nature of the sector. When discussing technology for farming land, he said that solutions can vary from "automated irrigated systems in some countries to intensive farming in others". He said that agriculture is "a valuable segment for IoT but difficult to scale. For us, it is very much a local application that changes from place to place".

Chart 5. Share of farm size count globally (hectare)



Source: Our World in Data 2016

Chart 6. Smallholder farms produce a third of world food (<2 hectares)



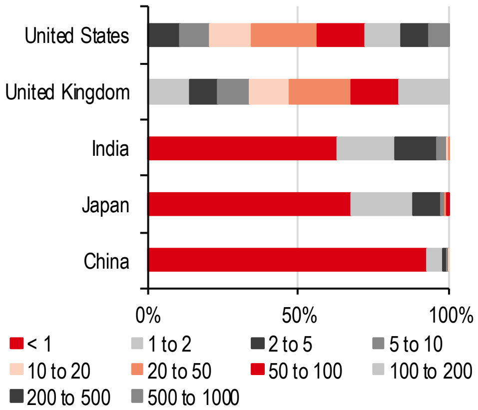
Source: Our World in Data 2018

Smallholder farms generate a third of global food…

So the question arises: how fragmented are farms and how does it relate to the productivity of the land as we discussed previously? First, let's look at productivity. Chart 6 highlights that smallholder farms (less than 2 hectares) generate about a third of global food: more specifically smallholder farms produce 32% of the world's food, 29% of global crops and uses 24% of agricultural land.

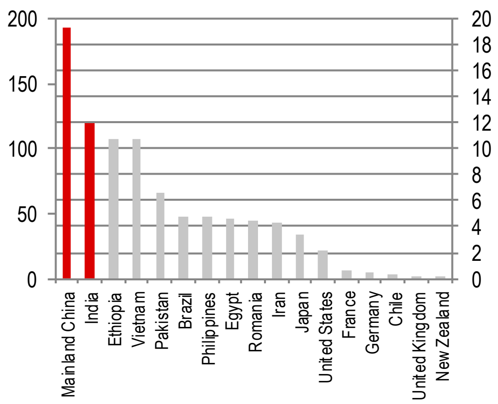
However, it isn't correct to conclude that the world's small farms produce most of its food, which sometimes is assumed for example by the OECD, as suggested by the Oxford Martin School. Chart 5 shows us that the majority of farms are less than 10 hectares. Note carefully additionally, smallholder farms are not the same as family farms, which actually can be a misnomer, and can be larger than 2 hectares.

Chart 7. Share of farms by size (hectare)



Source: Our World in Data 2016

Chart 8. Number of farms (millions) (Red=LHS, Grey=RHS)



Source: Our World in Data 2016

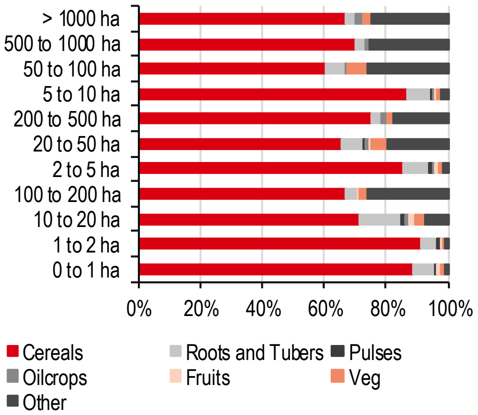
EM vs DM farm sizes

There is regional variation in terms of farm sizes. For example, chart 7 illustrates that in EM countries, 97.9% of farms are less than 2 hectares (eg, smallholder farms) in mainland China and the figure is 82% in India. Japan seems to be an outlier on this chart, wedged between mainland China and India in terms of share of smallholder farms. This could be due to its smaller landmass available (eg. mainland China has the 2nd largest landmass, India ranks 7th while Japan is 62nd out of 195 nations[2]).

In the DM, specifically in the UK and US, the same chart shows us that the percentage of farm sizes is more varied. For example, smallholdings are less than 14% in the United Kingdom and there are more mid and larger size farms. These observations are important in adopting the most appropriate types of technology for farm size.

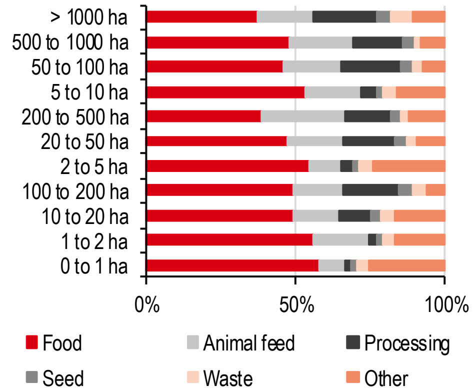
In terms number of farms, chart 8 shows us that mainland China and India lead the way with 193m and 120m farms, respectively. Contrast these numbers to the United Kingdom and the United States with 230k and 2 million farms, respectively.

Chart 9. Allocation of crops by farm size



Source: Our World in Data 2018

Chart 10. Allocation of farms by farm size



Source: Our World in Data 2018

2 CIA World Factbook

Smaller farms produce higher percentage of food on their land

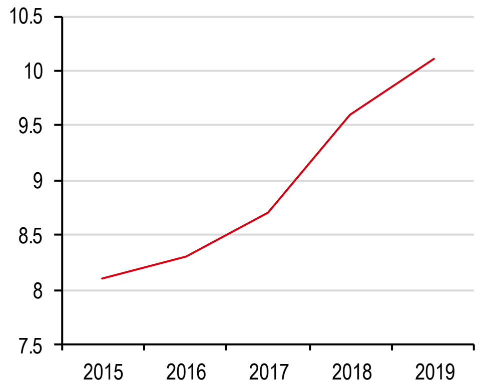
The type of crop a farm produces is important in determining the type of technology used to make it more productive and environmentally friendly. Charts 9 and 10 bring together the allocation of crops and farms by size. From the data, we see the smaller farms generally produce a greater share of food, compared to the larger farms having greater shares of processing and animal feed. We also see the smaller farms produce a greater share of cereals on their land than the larger farms.

Nutritional needs

Food insecurity and undernourishment increasing...

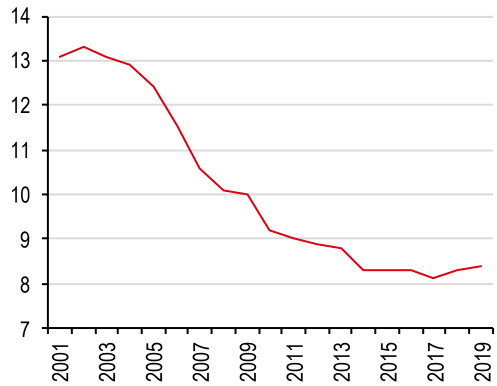
Undernourishment and food insecurity remain prevalent challenges for the world. Progress towards eliminating these issues has been slow, and since 2015, both the prevalence of severe food insecurity and undernourishment has ticked up, see Charts 11 and 12. It's also expected by the United Nations that the COVID-19 pandemic will worsen this further, therefore, food production needs to increase and the availability of the right food at affordable prices is required; modern farming technologies can help achieve this.

Chart 11. Prevalence of severe food insecurity in the total population annually (%)



Source: FAOSTAT

Chart 12. Prevalence of undernourishment annually (%)



Source: FAOSTAT

Calories, protein and fats trends…

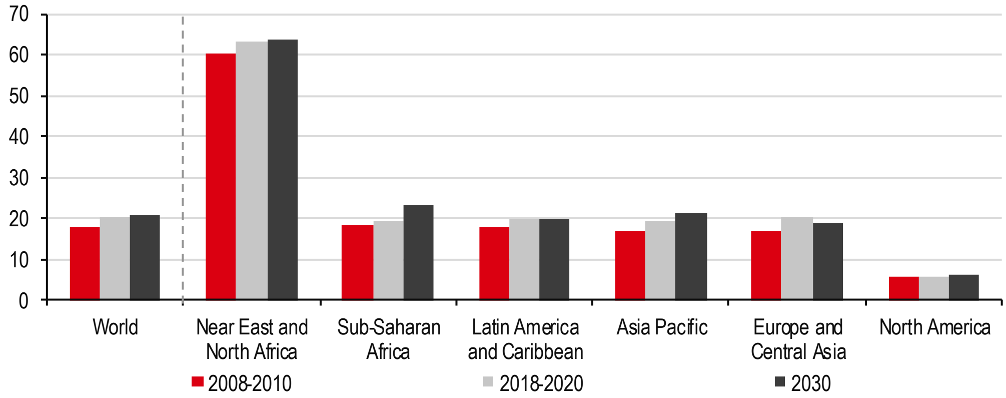
According to the UN FAO, North American and European citizens have both been getting a daily supply of more than 3,000 kilocalories of caloric intake since 1980 and both regions have grown to about the 3,4000 level today.

However, within South America, Asia and Africa, even though they have seen rising daily supply of caloric intake since the 1980s, it remains below or only very mildly over 3,000 kilocalories, with South America leading this pack, crossing the 3,000 kilocalories recently.

Relative to these regions, Africa is lagging the most with an average of just over 2,300 kilocalories daily. It is a similar story for the daily supply of proteins, with North America and Europe just over the 100g of daily protein barrier. South America has a daily supply of 86g of fat, with Asia at 78g and Africa behind them at 69g daily. Generally speaking, the UN FAO also observes that more than 50% of daily protein intake in the DM is from animals and in the EM more than 50% is from plant based diets.

Daily fat intake according to the UN FAO also tells us that North America and Europe are above the 120g level but South America, Asia and Africa are at or below the 100g level, with Africa lagging the most with a third of North America's intake.

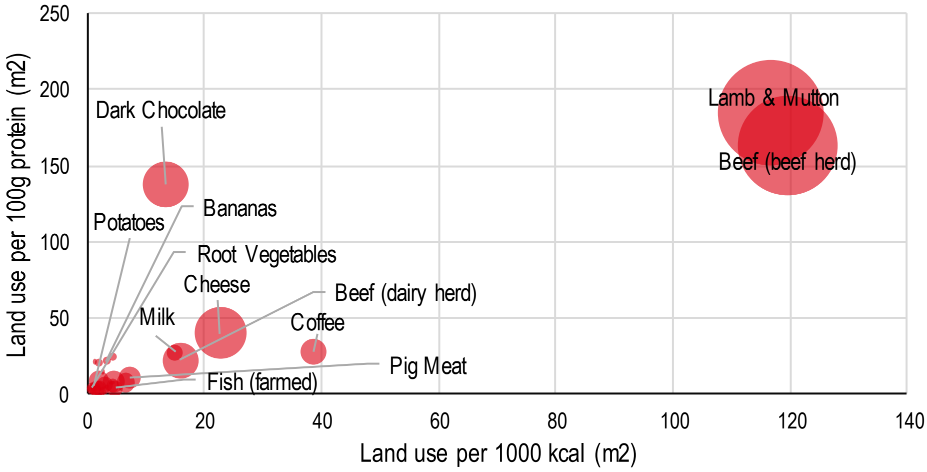
Chart 13. Imports as a share of total calories availability for selected regions (%)



Source: OECD FAO

Chart 13 shows us that the Near East and North Africa imports over 60% of its total calories available. This is roughly one third of the calories imported by most other regions globally. North America seems to be the region least dependent on importing calories, importing less than 10% of its calories' availability. Chart 14 shows us that in terms of land use intensity (vs. proteins and calories), beef, lamb and mutton are the worst offenders by a significant margin.

Chart 14. Land use of food: per 1,000 kilocalories vs. 100g proteins (m^2)



Source: Our World in Data (2018)
NB. Bubbles represent land use in meters squared (m^2) for foods

Emissions and other issues with agriculture

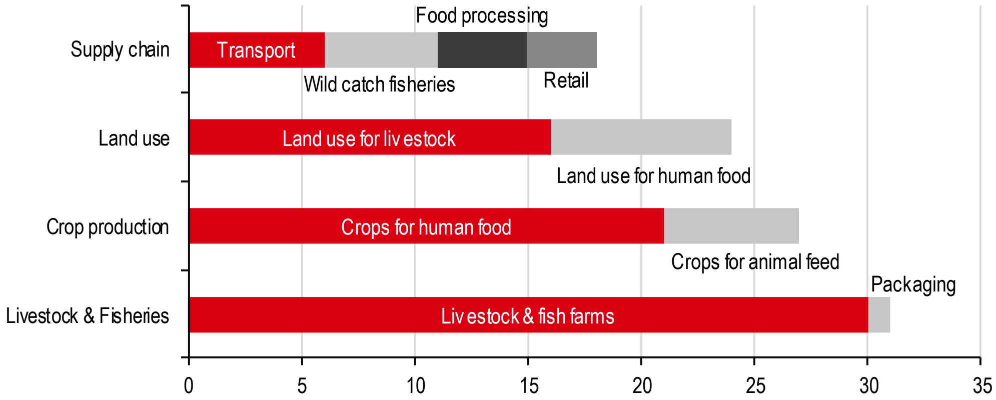
Environmental impact from food…

Food for thought: GHG emissions today

Feeding the world, and enabling the EM to catch up in terms of nutrition, is a force behind the need to make food production more productive, as we just outlined. However, there is another global pressing challenge for society too – namely getting to grips with climate change, and doing what we can do to embrace the reduction of greenhouse gas (GHG) emissions. In this section we will look at the state of play of emissions in the agriculture sector.

Its estimated that industrialised farming practises cause the equivalent of USD3 trillion a year environmental impact. This includes greenhouse gas emissions, air and water pollutants and wildlife destruction[3]. Additionally, the use of land is inefficient, with 60% of global agricultural land being used for livestock grazing, with an increased focus on producing animal feed and industrial ingredients for processed food. This transition highlights a contributing factor of how the prevalence of food insecurity has risen globally[4].

Chart 15. Global GHG emissions of food production (%)



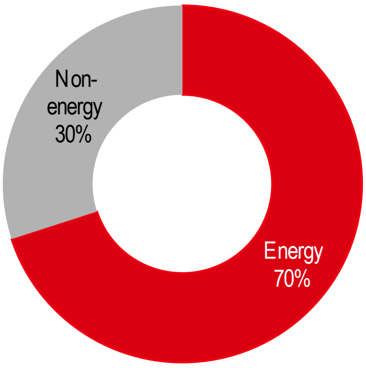
Source: Our World in Data, 2019, Poore & Nemecek, 2018

Food ecosystem is responsible for 26% of global GHGs

Broadly speaking, food related GHG emissions are responsible for roughly a quarter (26%) of global emissions. Chart 15 above illustrates how food related emissions are split between the four operations in food production – livestock & fisheries (31%), crops (27%), land use (24%) and the supply chain (18%). So, the majority of emissions is from livestock and fish farms, followed by crops for human food and then land use for livestock.

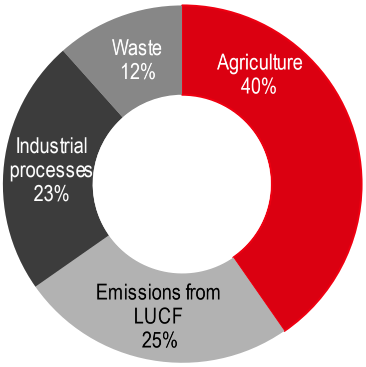
3 Trucost, S&P Global Market Intelligence
4 UN Environmental Programme

Chart 16. Global source of GHG emissions



Source: HSBC, IEA, EDGAR, Global Carbon Project. 2012

Chart 17. Global Non-energy GHG emission sources



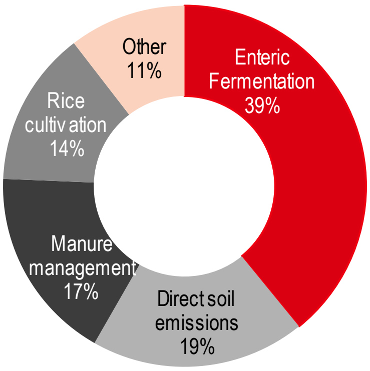
Source: HSBC, IEA, EDGAR, Global Carbon Project, Note: LUCF is Land Use Change and Forestry. 2012

Agriculture is 40% of non-energy GHGs

To identify areas where emission reduction efforts will be most effective in agriculture, we must recognise the sources and locations of emissions. Charts 16, 17 and 18 highlight that global emissions from agriculture represent 40% of the non-energy GHG emissions, with enteric fermentation the main source of agricultural emissions globally (39%). Enteric fermentation is the natural digestive process of animals, which produces methane emissions as a by-product, contributing significantly to agriculture's overall GHG emissions.

Enteric fermentation being the greatest share of the sector's emissions is a challenge because livestock is a major source of income for farmers – especially those in developing regions (FAO). Factors impacting enteric methane emissions are feed quality, animal size and environmental temperature. Farms with low productivity and high temperature, namely Latin America, South Asia and Africa face the greatest risk of increased emissions from this source. Improving productivity can transform a farm's energy intensity, reducing emissions, as well as creating social and economic benefits once quality and quantity of the farms produce is improved.

Chart 18. Sources of global agriculture GHG emission

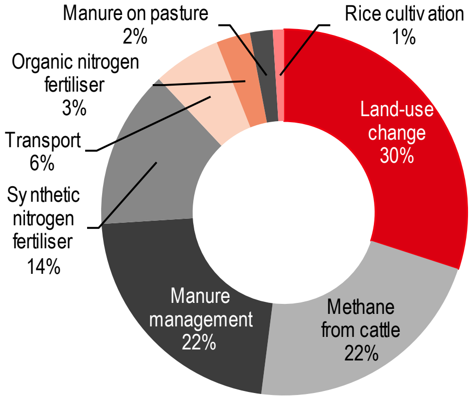


Source: HSBC, IEA, EDGAR, Global Carbon Project. 2012

EU diet emissions

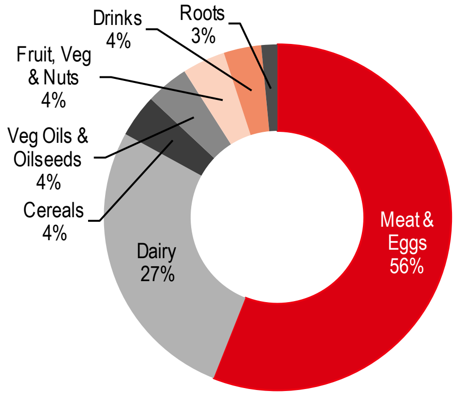
Taking a deeper dive into specific regions we see diets in the European Union (EU) and the share of GHG emissions from each source in the supply chain and by type of food. The majority of emissions are sourced from methane from cattle (included in enteric fermentation in the global data), manure management and land-use change – which describes the agricultural expansion resulting in the conversion of forests, grassland and other carbon sinks that result in the release of carbon dioxide emissions.

Chart 19. GHG emissions of diets in the EU by source



Source: Our World in Data, Sandström. 2018

Chart 20. GHG emissions of diets in the EU by food type



Source: Our World in Data, Sandström. 2018

Analysing the type of food and relative emissions, we see the majority (56%) of GHG emissions are from meat & eggs in diets, with dairy taking the second greatest share (27%). With some of the greatest shares of emissions from cattle/enteric fermentation and meat diets, we see an opportunity for changes to diets, improvements in productive efficiency and technology to aid the development of low-carbon food alternatives. See our discussion of alternative proteins in the next chapter.

40% of deforestation is due to beef/cattle production…

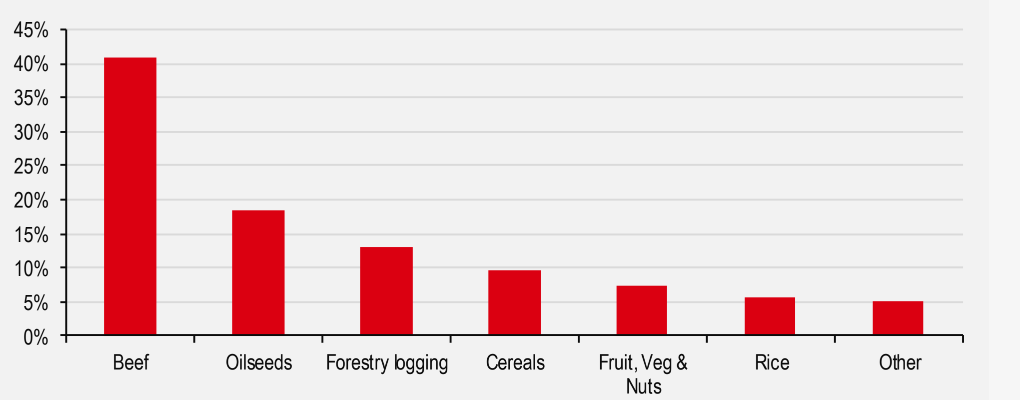
Deforestation and agriculture

Land-use change plays an important role in agriculture's emissions, as well as its impact on climate change and biodiversity. As the demand for food rises so does the demand for cattle, which requires land for both the livestock and food for them, ultimately creating a more destructive presence than just plant-based food does. As we discovered in the previous section, livestock use 77% of agricultural land, with unequal impacts on the World's calories (18%), highlighting this destructive process.

Although there are multiple causes of deforestation – others being forest fires and logging – developments in agriculture to a more sustainable future have the potential to reduce the rate of deforestation significantly. Although, the share of deforestation linked to agriculture varies from region to region, it is estimated that roughly 40% of deforestation is due to beef/cattle production[5] (see Chart 21), with this number being significantly greater for the South American region – 80% of deforestation in the Amazon is due to cattle ranching[6].

Please see *Deforestation and Climate Change (October 2021)* for more information.

Chart 21. Share of tropical deforestation drivers



Source: Our World in Data, Pendrill, 2019

5 'Drivers of Deforestation', Our World in Data, 2019
6 'The Beef Industry and Deforestation', Rainforest Partnership, 2016

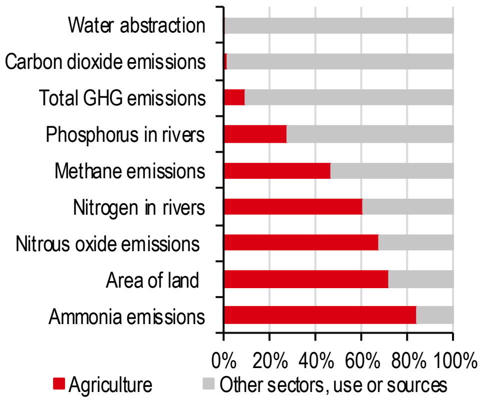
Agriculture generates pollutants and impacts biodiversity

Ammonia, nitrous oxide, methane, biodiversity, fertiliser and more

Looking into country level agriculture, we use the United Kingdom as an example. Using Chart 22 below, we can identify the areas where agriculture has the biggest impact on the country's emissions, pollutants and land use. Agriculture creates the majority of the contribution of ammonia, nitrous oxide and methane emissions, as well as 72% of land use and 61% of nitrogen pollutants in rivers.

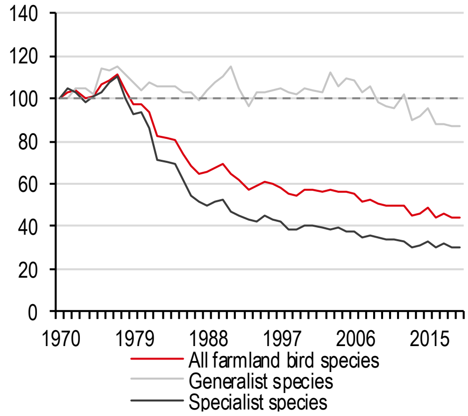
Agriculture contributes less than 1% to the UK economy[7] (compared to 4% of global GDP in 2019 according to the World Bank), and provides 75% of the indigenous food to the country. A key challenge faced is the ability to grow production without impacting the environment. In Chart 23 we illustrate the impact agriculture has had on farmland biodiversity. Between 1970 and 2019, all farmland bird species have decreased by nearly 60%, with specialist species declining by roughly 70%. The decline is partly due to changes in farmland management. 'Agri-environment' schemes hope to stabilise and recover these populations: these are land management and farm practices that benefit the environment.

Chart 22. Agriculture contributions in the UK



Source: UK Government 2019

Chart 23. UK farmland bird populations (indexed to 100 in 1970)



Source: UK Government

Agriculture impact vs. other sectors

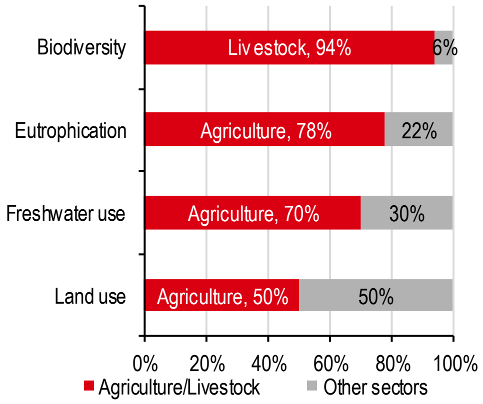
Charts 24 below illustrates the global environmental impacts of agriculture and livestock globally in comparison to other sectors. This supports our previous discussion on the impact the industry is having on biodiversity specifically.

Fertilisers…

Chart 25 highlights that 40-50% of the world is supported by synthetic nitrogen fertilisers. This innovation in the food ecosystem is important, to keep food demand in line with the ever increasing population growth; however, fertilisers can negatively impact the environment via air and water pollution. The challenge here lies with how to reduce the risk to the environment and encourage sustainable use. See the next chapter for a discussion on synbio innovations to combat this angle.

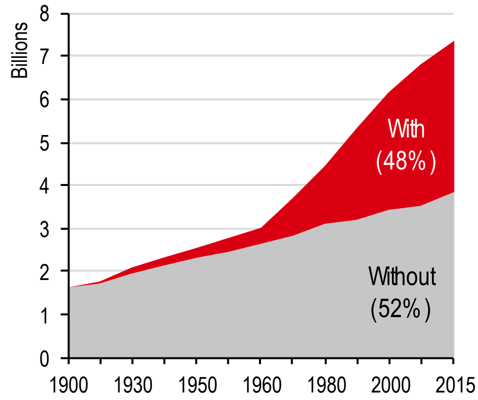
7 'Agriculture in the United Kingdom 2020', UK Government, 2021

Chart 24. Global environmental impacts of livestock and agriculture



Source: Our World in Data, Poore and Nemecek, 2018.

Chart 25. World population supported with and without synthetic nitrogen fertilisers (% of population in 2015 shown)



Source: Our World in Data, Erisman

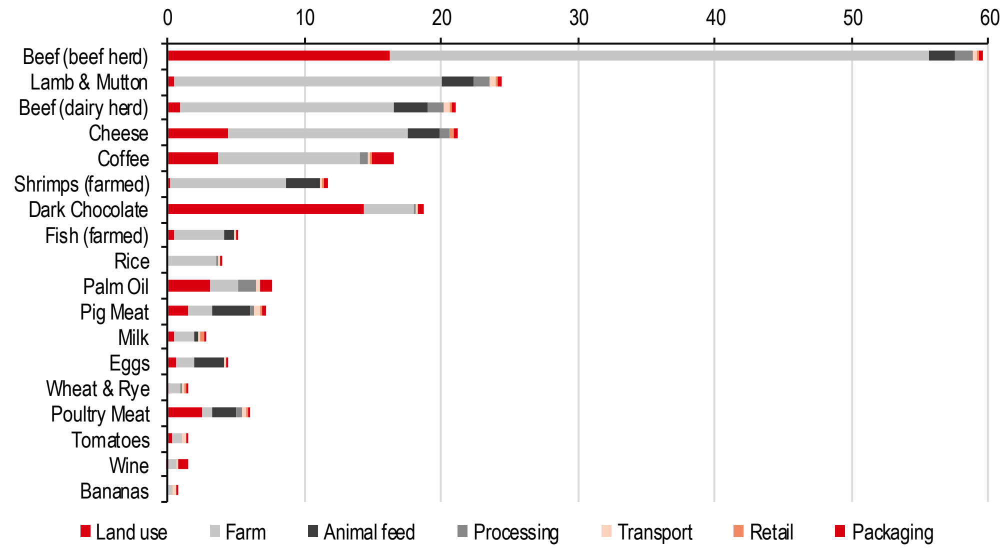
Food footprints

Which foods are the bad for GHGs?

Identifying trends across regions is useful, however, comparing individual produce types provides us with a comprehensive view of global food systems. Chart 26 illustrates total GHG emissions per kilogramme of various food and drink produce.

A kilogram of beef (beef herd) emits nearly 60kg of CO_2 equivalent GHG emissions, compared to a kilogram of bananas with less than 1kg of emissions. Observing the below chart generally, we can see that animal-based produce has a larger environmental footprint than plant-based produce, with farm level emissions (e.g. fertilisers, enteric fermentation) being the greatest proportion of the impact. Combining farm and land use emissions, these make up roughly 80% of each product's GHG emissions.

Chart 26. GHG emissions over the food ecosystem per kilogram of produce (kg CO_2 eq)



Source: Our World in Data, Poore and Nemecek, 2018.
NB. Data from 38,000 farms over 99 countries, ordered by emissions from farm level

Eat local or global?

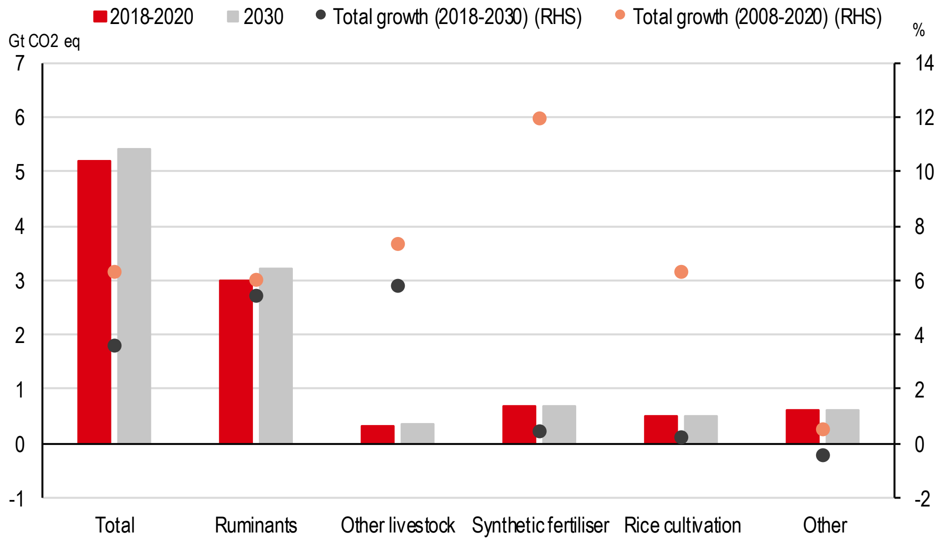
We can infer that practise at farm level has the most significant effect on a product's impact on the environment. Therefore, although eating more locally reduces transport emissions and benefits the environment, increasing productivity at the farm level has the greatest potential for reducing emissions – especially for animal-based produce. Additionally, eating locally may have environmental risks due to the use of energy-intensive practises to mimic weather conditions to produce food all year round – this is prevalent in plant-based produce.

GHGs in agriculture looking to 2030…

Projected agricultural GHG emissions

Agricultural activities account for roughly 12% of global GHG emissions[8]. The sector has the potential to make an important contribution to climate objectives, especially with the development of modern day farming technologies and applications. Chart 27 below illustrates projected GHG emissions in the sector, considering current policies and on-trend technological progress. Agricultural emissions are expected by the OECD-FAO to grow by 4% between 2018 and 2030, with livestock contributing to 80% of this increase.

Chart 27. Direct GHG emission from crop and livestock production, by activity



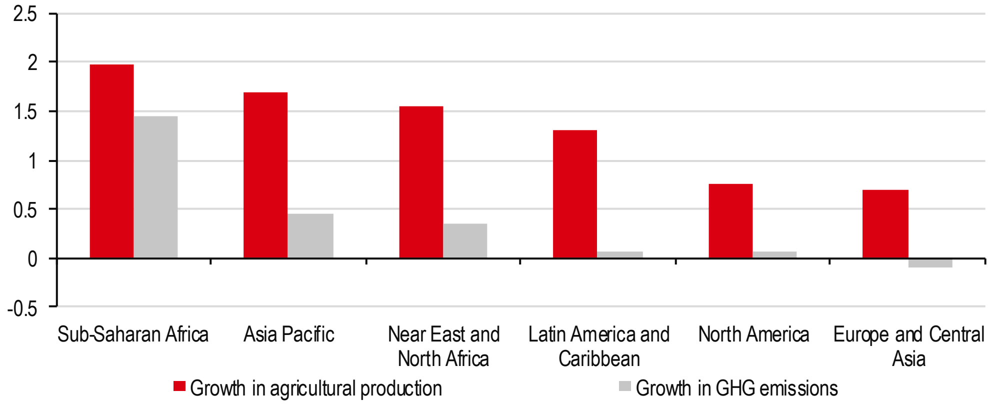
Source: OECD FAO

Are we expecting to make progress going forwards?

Looking at regional differences in projections (Chart 28), we see most of the expected increase in GHG emissions should occur in Sub-Saharan Africa and Asia Pacific. Over the next decade, agricultural GHG emissions in Sub-Saharan Africa are expected to rise by 16%.

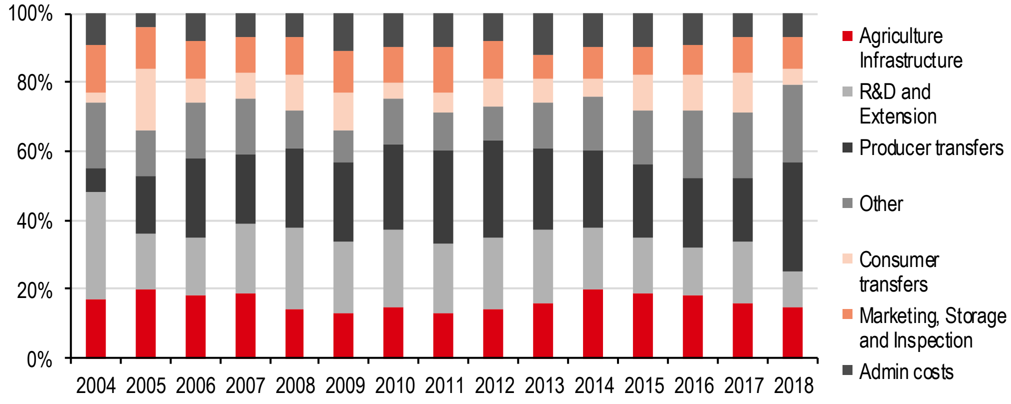
8 OECD-FAO Agricultural Outlook 2021-2030

Chart 28. Annual change in agricultural production and direct GHG emissions, 2021 to 2030 (% p.a)



Source: OECD FAO

Chart 29. Agriculture infrastructure and R&D trends



Source: OECD FAO

Should lower percentage in agriculture investment and R&D be a concern?

Across all the regions, agricultural production is expected to rise but emissions are expected to rise by a lower % in every instance by the OECD FAO. Some regions look set to experience significantly lower changes in emissions, due to yield improvements via technology and declining share of ruminant production.

However, one slightly concerning data observation is Chart 29, which shows us that the percentage of agriculture infrastructure and R&D spend seems to have been slowly trending down over the last few years. For these lower emission targets to be hit, we believe it will be paramount for society, investors and companies to continue to back and invest in smart farming technologies.

Water and agriculture

Responsible for roughly 70% of freshwater use, the agricultural sector is the largest consumer across all sectors globally. With water scarcity a major problem in most emerging economies, and agriculture being a dominant part of these markets, this exacerbates the water crisis. The sector is, in many ways, the perpetrator and victim of the risks associated with water scarcity. For example, it is a heavy polluter of the waterways with the use of fertiliser and pesticides, damaging the ecosystem and crop productivity.

In the majority of developed markets, and many emerging markets, the FAO states that pollution from agriculture has overtaken contamination from industry and settlements as the main polluter of inland and costal degradation. These factors include; Agrochemicals (pesticides), sediments and saline drainage, organic matter and drug residues.

One of the most significant contributors to the water pollution problem is the use of fertilisers, particularly nitrogen fertilisers, having significant implications for the quality of water, and local ecosystems. The situation quickly becomes a vicious cycle whereby water scarcity and climate change lower agricultural yields and thus more fertiliser is required to improve productivity. Greater fertiliser use contaminates local water sources, exacerbating water scarcity challenges, and the cycle begins again.

See *The Water Crisis (September 2021)* for more information.

Society and agriculture

Inequality between developed and developing nations is evident in the agricultural industry. This includes both producers and consumers of products. In some instances, agriculture enhances this inequality. The development of smart farming technology can be focused on large commercial farms aiming to increase yield and manage aspects such as water and energy but lots of local projects are taking place, as outlined in the connectivity section in the next chapter.

Knowledge inequalities remain one of the biggest challenges when adopting new technologies. In agriculture, smallholders lack access to education, best practices, advice, data and information on the most appropriate technologies and how to use them. However, here lies the opportunity for upskilling, by investing in agricultural advisory and extension services. This benefits society as a whole as knowledge grows, yields increase and financial rewards are enhanced.

Gender inequality in agriculture also remains a challenge. On average in developing nations, women make up 43% of the labour force in agriculture. Less than 20% of landholders are women due to legal and cultural constraints. It is estimated that if women had the same access to productive resources as men, technology for agriculture in this instance - yields could increase by 20-30%. This would raise total agricultural output in developing countries by 2.5-4% on average. Productive resources including land, technology, education, modern inputs and financial services[9].

Ever increasing food production demand and developments in the agricultural sector which have had to be made to keep up, have caused some concern for human health. Examples include:

- Antibiotic resistance bought about by the use of antibiotics in animal agriculture, potentially reducing the effectiveness for humans
- Pesticide exposure during application and airborne dust/droplets, contamination in water and food, with toxic effects on humans
- Water quality impacted by the use of fertilisers
- Disease control and virus transmission from animals to humans

Regarding the use of technology in agriculture, and the rise of automation and robotics, the impact this has on jobs is one to be considered. Agriculture has one of the highest risks of job automation across all sectors. An agricultural worker has an 87% risk of automation, with technologies such as big data analytics, internet of things and e-commerce/digital trade being the most likely technologies adopted in the industry. As many emerging economies have a large share of their job market in agriculture, this makes them particularly vulnerable to automation, compared to those with a higher shares of service jobs. See *Robots and Jobs (November 2021)* for more information.

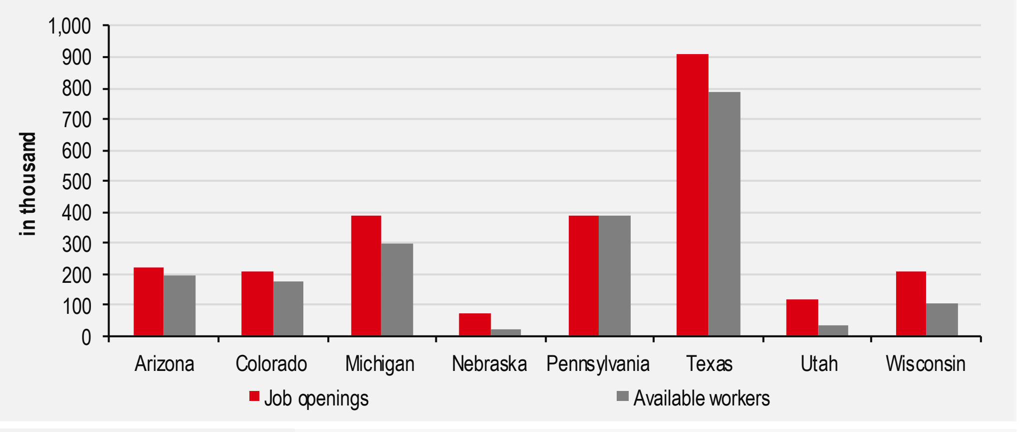
9 'The state of food and agriculture: Women in agriculture', FAO, 2010-2011

Labour shortages

The risk of job automation in the agricultural sector is high. For example, the Office of National Statistics in the UK says there is a 65% probability of agricultural machinery drivers at risk from automation, and other related agricultural jobs at around 35% at risk from automation.

Chart 30 below illustrates the volume of worker shortages in the United States at the world's largest meat processing company JBS. As well as improving efficiency and productivity, worker shortages are driving the adoption of automation and robotics technology by firms such as JBS, in the food production sector. The pandemic has also exacerbated labour issues within the agricultural sector.[10]

Chart 30. Worker shortages in the JBS Beef processing facilities in the US (as of Nov 2021)



Source: U.S. Chamber of Commerce Analysis, BLS

10 "The anxiety is off the scale: UK farm sector worried by labour shortages", The Guardian, Augest 2021.

Smarter tech to feed world

- The agriculture sector presents a host of intertwined environmental issues, which can only be exacerbated in the quest to feed the world
- We look at a number of key technologies available today which we believe can make farms and the agriculture sector smarter…
- Hence addressing environmental and other concerns from food production

Working smarter on farms…

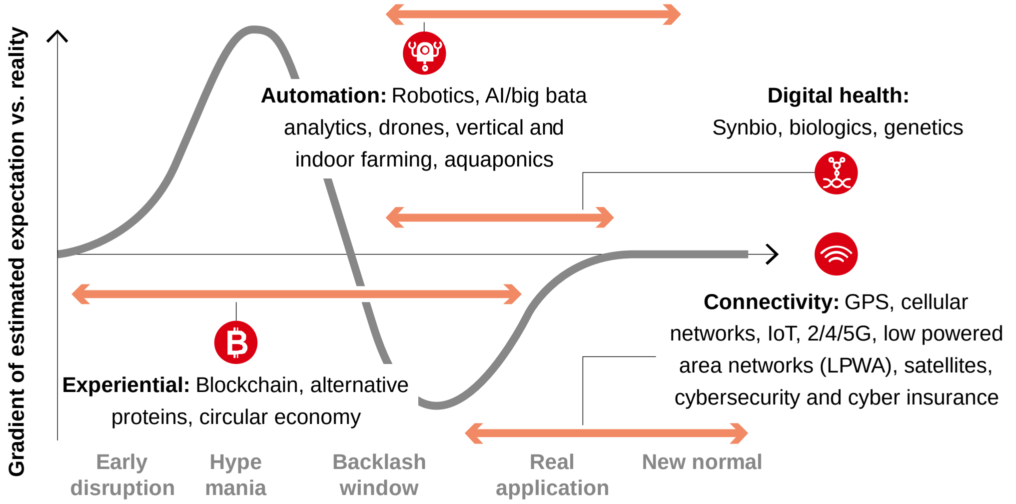
21st century farms…

The rise of disruptive technologies

Smart farming naturally includes technologies such as robotics, with connectivity being a crucial part of the jigsaw. At our expert event on smart farming in 2021, the panellists highlighted how due to farms being in rural areas, good, stable connectivity was a pressing issue to be solved. Good connectivity is needed in these smart farms, so their systems can operate using Internet-of-Things to track and automate activity. Farms are also starting to use big data, artificial intelligence, drones and blockchains to process and make sense of activity in real-time.

However, as the farm becomes smarter, allowing the production of crops, feeds and livestock to increase yields, reduce water use, energy and labour - this digitisation also brings issues of cybersecurity and hacking.

Chart 31. HSBC Disruption Framework: Smarter farming



Source: HSBC

Thinking more farming innovations…

We believe there is value in understanding smart farming beyond the traditional definitions of simply pure digitisation. So we look at how innovations such as vertical farming, hydroponics, alternative protein for human consumption, synthetic biology and animal protein/pain killers can help with reducing water use, emissions and improving ethics in the modern agriculture setting. See Chart 31 for our HSBC Disruptive Framework, to see how commercial the various technologies are today.

In this chapter our analysts around the world help us identify the key technology trends enabling the farms of the 21st century to not only improve productivity to feed the world but also do it in a sustainable fashion. See Table 1 giving a high level view of which sustainable themes various technologies in this chapter tick.

Table 1. Smart farming matrix: Impact on sustainability growth themes

Technology or application	Emissions	Crop yield	Land	Water	Animals	Labour	Ethics/social
Connectivity	○	●	●	●	●	●	
Robotics	○	●	●	●	●	●	●
AI, big data & data analysis	●	●	●	●	●	●	●
Drones			●			●	●
Blockchain	○		●	●	●	●	●
Cybersecurity	○	○	○	○	○	○	●
Alternative proteins	●				●		●
Synthetic biology	●	●	○				
Genetics, medicines	●	●	●	●	●		
Vertical/indoor farming	●	●	●	●		●	●
Circular economy	●		○	○	○		●

Source: HSBC
Key: ● = Direct impact, ○ = Indirect impact
Key: Connectivity framework = red, Automation = orange. Experiential = blue, Digital health = green

We additionally take on board thoughts from our Banking and China Internet teams. They tell us how the new generation of farming technologies might get lenders involved, and how even though China has a low use of digital technologies in agriculture, this is starting to change, especially with government support.

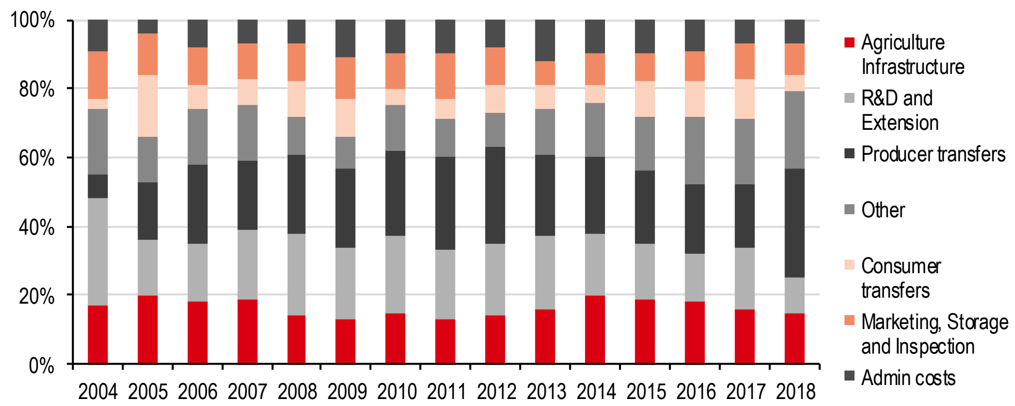
Agriculture is a USD3.5trn industry

Smarter farming market size

Global GDP in 2019 was estimated to be USD87.6trn by the World Bank. It also estimated agriculture's percentage of global GDP to be about 4% in the same year. This implies that global agriculture GDP in 2019 was USD3.5trn.

The chart below shows us that total R&D spend in agriculture was 10% of the total value of the agriculture sector in 2018, with an average of 15% for the previous half decade. We approximate that agriculture R&D spend globally was about USD350bn in 2018.

Chart 32. Agriculture infrastructure and R&D trends



Source: OECD FAO

Smartening agriculture could be a USD90-138bn market by 2030…

In 2020, the smart agriculture and food tech (or AgTech) was estimated to be USD22.3bn in its market cap by venture capital firm Finistere Ventures. This included investments ranging from technology in precision ag to alternative proteins. From 2011 to 2020, this was a CAGR of 56%. So approximately, this means AgTech is about 25% of agricultural R&D spend. We estimate that AgTech could grow by 15-20% through to 2030, valuing the space at USD90bn-138bn by 2030.

Smarter farms through robots and connectivity

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The future farm essentials: robots in disguise

Digital technologies and robotics can help create fully autonomous solutions that are sustainable, in the sense they can be more resource-efficient, and cost effective because they help reduce overall labour costs.

Emerging applications of robots or drones (see next section for more details) in agriculture include weed control, cloud seeding, planting seeds, harvesting, environmental monitoring and soil analysis. Automation and robotics for smart farming encompass a range of technologies, which include the below:

Robots to make farms more sustainable…

1. **Autonomous tractors**: these allow driverless farming to help ensure quality and lower labour costs. In August 2021 a leading Agtech supplier John Deere acquired Bear Flag Robotics for USD250m to accelerate the adoption of autonomous driving technology in farm vehicles. Further, e-tractors exchange data on use and charging needs to optimise energy consumption.
2. **Harvesting robots**: vegetable picking robots, equipped with machine learning to identify and harvest a specific agricultural crop, are enabling automated harvesting.
3. **Robotic milking systems**: allow cattle farmers to automate the milking process. Milking robots are the largest and most established agricultural robot technology.
4. **Drones**: remote-controlled consumer or prosumer drones are used for aerial image acquisition.
5. **Controlled environments**: using building automation solutions for vertical farms, where optimised growing conditions for plants and other foodstuff products are created in a reliable and energy-efficient way. Also known as Controlled Environment Agriculture (CEAS) in this domain.

Agri bots USD19bn by 2026e

Agricultural technology news site AgriTech Tomorrow pegs the global agricultural robot market size at USD19bn in 2026e, rising at a CAGR of 10% (based on a December 2020 study).

A November 2021 UK government study estimated that the agriculture robot density in the UK (measured in robots per million hours worked) would increase from below 1.0 by 2025 to around 8.0 by 2030 and further to 21.6 by 2035. The study also predicted that in the agriculture sector up to 30% of tasks could technically be automated by 2035, equivalent to an estimated GBP4.5bn of GVA, driving productivity increases of 0.9% relative to baseline by 2035, adding an estimated 0.7% to GVA relative to baseline.

Is investment cost a barrier to entry?

High initial investment costs are a barrier to growth for the agricultural robot market. Other identified barriers in the agricultural sector include drone regulation; digital skills shortages; and problems with research and testing.

Example 1: Farm robots and automation in action

Siemens Autonomous Agricultural Pods, or AgPods, allow farmers to control and monitor the growth of any crop, from anywhere at any time. The Siemens MindSphere open IoT operating system employs machine learning and sensors to measure moisture, pH, and temperature for predictive analytics. This helps increase the yield rate.

CubicFarm, a Canadian listed company uses hydroponic technology in an automated system called Hydrogreen.[11] It enables farmers to grow their own nutritious livestock feed, all 365 days a year, in an indoor climate controlled setting, using AI and robotics – removing the need for labour. Their feed is grown over 8 independent stacked tiers. First a bed of wheat or barley seeds are spread to each level automatically. Growing functions such as irrigation and lighting are automated too. It takes about 6 days for the seeds to germinate and create 15,000kg of fresh feed. The company says that compared to traditional crops, their automated system uses 95% less water without fertilizer or pesticides. The feed is then cut automatically and mixed with the rest of the cow's ration. Its business model is to sell modules for its system and also a subscription model for seeds, nutrients, substrates, consumables and consulting services. It sells its technology in Canada, the US, mainland China, Indonesia and the Middle East.

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The 21st century connected farm…

Internet of Cows?

Farming is a productive process that, as an industrial process can benefit from precise monitoring of conditions throughout the different stages. Optimisation and productivity gains are increasingly important given the uncertain conditions that dictate the output, including climatic conditions or pest control, to name a few. It is also key when considering the finite (and increasingly under constraint) resources such as water. A failed harvest has no substitute other than a long wait until the next seasons' cycle.

Farming benefits from technology through three dimensions: first, by predicting the environmental parameters (rain, temperature, wind), second, by measuring parameters on the ground (crops, livestock, inventories) and third by collecting and analysing data to build a decision model, which in turn would improve productivity on the ground. From a technology standpoint, we observe a combination of satellite and mobile technologies including 5G supported drones:

- **Satellites:** provide the underlying data to observe and model the climatic conditions but also through spectral analysis satellites images can help to predict the output of a specific crop and determine actions to fix underperforming plots. GPS (Global Positioning System) is supported by 31 satellites, which from their 20km-away orbit can help a farming device to move with precision or to define precisely the boundaries of a field. Europe has built EGNOS (Ex Galileo) to reduce its dependency on the American GPS system. Similar systems have been developed by Russia (GLONASS) and China (Beidou).
- **Mobile**: cellular networks can support farming using IoT (Internet of Things) technology. Smart farming devices can monitor climatic conditions on the ground (sensors indicate if a field needs watering or fertilizer) or help in making decisions on when to feed and milk animals for example.

5G IoT for sensors and mobility

Satellite technology as a support for smart farming is well known, but the development of 5G technology could take farming to another dimension. The IoT ecosystem is currently supported by 2/3/4G technologies but also by low powered wide area networks (LPWA) that can support Machine to Machine and IoT devices that don't require high data loads.

5G technology will expand the capacity of IoT. The standalone version of 5G (also called Release 16, an end-to-end 5G architecture from core to access, with a cloud-native configuration) can support one million IoT devices per square km, with improved power and connectivity controls. Analysis in a report by the European Telecommunications Network Operators' Association in 2022 says that the agriculture industry used 2 million IoT in 2020 and it expects this to grow to 53 million connections by 2029, which is over 26-fold growth. Contrast this to the automotive sector using 71 million IoT in 2020 and growing to 250 million by 2029, which is just over 3x growth.

11 Illustration of automation in smart farming from our Disruptive Technology team.

Drone as a Service or Robot picking fruits?

Another feature of 5G is ultra-reliable and low latency communications. This feature could be vital for automated flying drones (checking crops and livestock) but also to support mobile vehicles with robotic arms that could pick fruit for example: the connectivity would allow the sensors/camera to identify the stage of development and the actions to take thanks to computing power sitting at the edge of the network).

Software is playing a key role: the amount of data collected by satellites and mobile sensors can be processed and supported by AI and ML processes, leading to higher productivity eventually.

Example 2: Farms of today powered by IoT
To illustrate an operator business case for IoT, we would refer to Vodafone. The European operator is a global leader in IoT connectivity, having more than 130m connected devices on its platform. Most of the IoT revenue is derived from connectivity (growing 10% pa in 2021-2024), while hardware and solutions are small but growing (respectively 11% and 30%+).

Vodafone would help its clients from the legal and regulatory aspects, the sourcing of equipment the system integration and the go to market solution (marketing material, pricing and support). Operators can defend their position by creating verticals and leverage the process across the same industry (automotive, health, etc). We list a few examples of solutions that Vodafone offers to farmers and agriculture companies (source: Vodafone website):

- **Connected flour mills:** connected mill-grinders in 150 mills to a GPS signal to relay data every five minutes to a centralised cloud platform, with information on everything from nutrient ratios to cooling measures, and from weight readings to feed-screw speeds
- **Connected vineyard's**: combined NB-IoT sensors and satellite imagery, to measure the humidity, temperature, soil conductivity, and water absorption around harvest
- **Connected cattle feed:** 2G/LTE connectivity and cloud analytics to monitor the nutritional contents going into its mixer wagons. Enables farmers to fine tune decision making and herd management, by drawing on live data from mixer wagons and a vast "feed efficiency database"
- **Connected livestock:** 2G sensor that attaches to a cow's tail and measures the movement to predict when it's going to go into calf. When a cow's contractions reach a certain level, the sensor sends an alert to the farmer's phone, via Vodafone's IoT platform, up to one hour prior to labour

New(er) fundamental tech: Digital farming, big data/AI, drones, blockchains and cybersecurity

Digital farming

Digital farming is primarily about the use of data-driven insights to optimise farm management, but also includes online marketplace for farm products. With AI and cloud computing systems, the data generated at different levels through precision farming tools can be integrated to generate region or field or even each plant specific insights to advise the farmers on the right time of sowing and tilling, what crop to sow, how much and what fertilizers to apply and more. For instance, field specific crop and soil conditions available through precision farming can be combined with geospatial/satellite data and pricing information. These data can be used in predicting weather, pest attacks and price information. The benefits are higher output and cost savings to farmers. For instance, based on Microsoft's field trials in India, farmers were able to increase yields in the range of up to 30% through the use of Microsoft's advisories.

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Some of the advisory services are offered via mobile based apps free of charge which facilitate easy adoption among the farming community. Paid services are available at a relatively lower cost (say USD5-10/acre) with limited investments in hardware by farmers. The simplicity and low cost of such mobile based services means that adoption of this type of technology is likely to be much faster.

Return on investment for farmers…

The return on investments on the use of digital agriculture services, in general, seems compelling. For example, Accenture has said that there is a USD55-110/acre increase in profits due to digital agriculture. This is larger than the overall profitability per acre, which is about USD250-300/acre for corn and soybeans in the US, while the cost for digital ag service is as low as USD5-10/acre, depending upon the level of service.

Table 2. Return on Investment on Farm Edge's comprehensive package at USD6/acre

Services	Details	ROI (USD/acre)	Acres tested
Variable Rate Technology	Targeted response in select areas within the field that aids higher yields and optimum input use	31.84	9.5m
Nitrogen-Manager	Reduces nitrogen use by 10% and increases yields by 5%	36.30	663k
Moisture Manager	Decision making on irrigation, nutrition needs and yield forecasting	27.3-49.3	172k
Analytics	Seed selection, planting dates, input efficiency etc	5-120	6.4m
Field mapping	Maps Soil and crop health, harvest, scouting etc	3.25	6.4m
Weather sensors	Hyper local weather information	1.26	12.8m
Predictive modelling	Disease and pest modelling and planning field operations	7.75	11.9m
Equipment tacking	Measuring productivity and fuel performance, speed regulation and helps in predictive maintenance	3.0	12.8m

Source: Farmers Edge

The charges by Farming Business Network, a co-op in North America, is lower, with a flat USD700 per user per year. As can be seen in the table below, the ROI for digital services range from USD3-120/acre based on the case studies observed in over 6-13m acres by Farmers Edge. The advantage is that some of these services can be accessed simply through mobile apps, and a typical full package service would just require investments in basic hardware like guidance systems and low cost sensors, that are already used widely in developed markets.

Barriers to adoption and key players

Full-suite services such as field-specific advisory require investment in hardware that could be a challenge in most EM markets where the small size of landholding and upfront capex costs do not justify the economics. Hence these markets are likely to be more focussed on basic services that also limit the benefits to farmers. High speed internet connectivity in farms, a pre-requisite for the smooth functioning of connected systems, is another barrier even in developed countries where the 5G rollout is still in the early stage.

Regulations and policies that restrict or limit the use of UAVs/drones could increase the cost of data collection and limit the offering of services. The key challenge for companies that are investing in digital farming is the way to monetise of data. Those that are using the data to improvise their core business or to upsell/cross sell products are more likely to succeed than the companies that offer fee based services. Hence, many start-ups and companies are developing open source platforms to gather necessary data input. Again, regulations that restrict use of data can be a headwind in the path to monetize the data.

We think companies such as Nutrien Ltd, Yara, Corteva and Deere & Co have early-mover advantage due to the aforementioned disruptive trends. Nitrogen and crop protection companies might also face headwinds from potentially reduced input use. Farmers Edge is a pure digital ag company listed in early 2021.

Example 3: AI and big data making food sustainable in CEA facilities[12]
AppHarvest is US listed AgTech company (via a SPAC in 2021) and it hails from Appalachia. It grows fruits and vegetables through an indoor farming process, leaning into various disruptive technologies. Last year, AppHarvest acquired a company called Root AI, which enables robots to use intelligent tools to make food sustainably. The company it acquired will enable it to use AI, big data in conjunction with robots to manage its high-tech indoor farms. Its technology means that the robots can collect data it harvests, which enable it to evaluate crop health, precisely predict yield and optimise operations of the controlled environment agriculture (CEA) facility.

According to AppHarvest founder and CEO Jonathan Webb, one of the key challenges of agriculture is to accurately predict yield, as many downstream decisions such as work schedules, transportation and retail planning are based on this output. He believes AI (through big data) can be used to solve this issue. The robot and AI system from Root AI has been taught over the last few years on tomato image data sets, so that it can identify more than 50 varieties in different growing environments and various stages of maturity. This analysis of data lets the system learn how and when to harvest and uses a variety of technologies to gather the data such as infrared lasers to generate 3D colour scans. The AI and robot uses a built-in feedback system which learns as it operates.

AppHarvest said “enhanced data collection for each plant through the robot can lead to insights that teach us how to design better, more resilient food systems that are reliable and that produce more with fewer resources”. AppHarvest also uses AI technology from a company called Koidra, which helps collect data continuously from an indoor farm microclimate using over 300 sensors.

12 Illustration of AI and big data for smart farming from our Disruptive Technology team.

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Drones

Specialised drones are used for image sensing and pesticide spraying which will result in cost savings to farmers through increasing labour efficiency and reducing pesticide use. China, which is a leader in drone manufacturing, has seen exponential growth in drone use for agriculture over the last two years. We think drones will see an increasing adoption in the future due to the following reasons:

- **High efficiency and labour cost savings**: Drones are much more efficient than manually spraying of pesticides, a practice that is followed in many emerging markets such as India, Brazil and Indonesia. Drones are much more cost and input efficient than a conventional sprayer and can reach difficult terrain that cannot be easily accessed by machines.
- **Low pesticide use**: According to various drone companies and testimonies by farmers as reported in news articles, drones can save pesticides use by 30-80% depending upon the crop.
- **Service-based model aiding easy adoption**: A farmer can hire a drone rather than spending upfront on buying a new drone. Also, it helps overcome issues related to a lack of training. In China, farmers can hire a drone and a pilot at CNY15 per hectare for spraying, considerably lower than labour costs.
- **Aerial mapping instead of manual scouting**: Drones with multispectral and hyper spectral sensors can capture information on soil moisture, crop health, pest impact, and nutrient absorption/deficiency. The data collected can provide insight on preventive measures and issues can be addressed in a timely manner that prevent yield losses, and are more efficient than manual scouting.

Key barriers and drone players

Regulations and policies that restrict or limit the use of UAVs/drones are the key barriers. Many countries require a drone to be operated by a trained professional who holds the requisite license, which could increase the cost of operations. China's DJI, PrecisionHawk in the US and TSX listed AgEagle are notable players in drone manufacturing.

Example 4: Is it a bird, plane… no it's a farm drone

Start-up companies have said that drones can save a significant amount of labour charges and pesticide use. Typical labour costs for spraying pesticides in India are INR400-500 per day and one person could at most cover one acre or a little more in a day. A fleet of drones can cover as much as 500 acres in a single day with effective costs less than 1/4th of manual labour. China based DJI also has a similar claim on coverage per day. The service oriented models and considerable cost savings will likely result in rapid adoption of drones in the near future.

The drones also save a lot on pesticides with claims by drone companies suggesting a 30-80% reduction in pesticide use depending on the crop. On the use of aerial mapping, companies such as Precision Hawk and Airinov's claim advantages such as yield maximisation and efficiency improvements. For example, according to PrecisionHawk, drones can survey 50 acres in an hour while manual scouting would take 11 hours to cover an acre, and on top of that, it comes with 25% more accuracy.

Another example for illustration is AgEagle, a US based and listed company which provides drones, sensors and software.[13] It utilises fixed-wing drones to enable precision farming. The company has a service product called FarmLens which takes images from drones and stitches together thousands of high resolution, multi-spectral images which generate detailed maps covering disease and pest infestations, to understanding weather impacts and improper irrigation – which can be detected before being observed by the human eye and are lower cost than satellites or manned aircraft flyovers.

13 Illustration of drones for smarter farming from our Disruptive Technology team.

AgEagle has said it has processed more than 2 million acres of crops using the FarmLens system, analysing data from over 50 countries and 53 types of crops, generating 11,000 compressive crop reports. FarmLens can be used on PC or mobile. All of these data are collected through its fixed-wing drones, called the RX-60. It is able to launch itself using a catapult and flies/lands on its own. The drone is able to cover 400 acres and can fly 60 minutes on a single battery charge.

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Blockchains

Blockchain technology empowers the traceability of all kinds of information in the food supply chain from seeding and farming to harvesting, packaging, delivering and selling. Key benefits include:

- Ensuring the safety of food;
- Improving efficiency as the tracing can be done in seconds; and
- Enhancing famers' income as they can get fair pricing for high quality food.

In Asia we observe that internet companies with cloud services all provide this service to farmers, including Alibaba, JD and Tencent:

- **Ant Chain (蚂蚁链) of Alibaba** covers 3bn products of 140k categories in over 100 countries. Sales of Ant Chain related to agriculture grew over 12 times in 2020, among which agriculture product tracing increased by 7 times. For example, it helped a farmer in Anhui in tracing the food origins of pears and pear syrup products. Thanks to enhanced transparency and consumer trusts, the farmer can sell his products at higher prices and has doubled sales in the last year.
- **JD Chain (智臻链)** covers 1bn products for over 1,000,000 companies in China (Company Sustainability Report for 2018-2020).
- **Tencent** targets to develop 100 agriculture brands in 3 years by providing financial, technology and traffic support, and block chain product tracing is one of the technologies (*Sohu news*, 2021).

Example 5: Bayer, blockchains and farms[14]

The German pharmaceutical and life sciences company Bayer recently signed blockchain partnerships with BlockApps in the US and Brazil and with Ant Financial in Asia. This collaboration with BlockApps is called the TraceHarvest Network. It uses Ethereum and is differentiated from other blockchain apps because of its ability to track seeds before planting. This includes information about their source and where they were acquired.

The objective of this project is to help reduce manual inputs, manage water and pesticide/herbicide usage. It can also increase productivity and reduce the risk of contravening any rules relating to environmental considerations or crop type in any given location. BlockApps believes that the TraceHarvest Network can also be used for carbon offsetting/credits at some point. This is also part of Bayer's digital farming strategy. The collaboration with Ant Financial seeks to mimic a similar model for food supply in Asia.

Cybersecurity and farm theft

Smarter farms mean more digital threats…

The increased adoption of technology in any sector doesn't come without its challenges, especially when it comes to cybersecurity. A 2018 report from the US Department of Homeland Security looked at a range of cyber threats that face the "precision agriculture" section, as this space adopts "new digital technologies in crop and livestock production". It found various cyber threats to agriculture supply chains including: theft of confidential agriculture data, corrupting data to disrupt crop and livestock, damage sensor networks to harm health of animals and more.

14 Illustration of blockchain applications for smarter farming from our Disruptive Technology team.

Furthermore, the FBI said in 2016 that agriculture is becoming "increasingly vulnerable to cyber-attacks as farmers become more reliant on digitized data", this includes threats via ransomware. 2021 saw a very high profile ransomware attack on JBS, which controls about 25% of the cattle processing in the United States. Last year also saw a Minnesota agriculture company called Crystal Valley Cooperative become the target of a ransomware attack, which took its operating systems offline. It left the company unable to mix fertilizers or carry out orders for livestock feed.[15]

Michael Daniel, chief executive of Cyber Threat Alliance said recently "The agriculture industry probably lags behind some of the other industries that have been hit harder by cyber crime". Crowdstrike, the cybersecurity firm, put the agriculture ecosystem into context for cybersecurity by saying "depending on who you're talking to in the ag industry" and outlining that multinational conglomerates that have intellectual property (IP) make it a top of mind issue to protect, however "as you get down the food supply chain… they probably think about it less seriously". As of today, no mandatory cybersecurity regulations govern the agriculture business in the US, only guidelines. However, the USDA and DHA are suggesting that the sector creates a cyber- threats clearinghouse.[2] The food sector in the US abandoned its intelligence sharing group in 2008.

As we outlined at length in our report "Cybersecurity – spend to defend" (2021), the insurance sector is also being used to defend against cyber threats and the agriculture sector is being serviced too. AXA has it's "Smart Farm Insurance" package for farmers. Our agro-chemicals analyst highlights another example, where the Indian agrochemical company UPL offers farm insurance products under its AgTech offering.

Application of smart farming: alternative proteins

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Introduction to the technology

What is alternative protein?

Alternative proteins cover the whole range of foods where plant-derived proteins are used to replace those traditionally derived from animals. The category can broadly be split into two main components: meat and dairy alternatives. Versions of these products e.g. tofu and rice milk have been part of the diet in certain regions for many years but, in recent years, technological advances have led to a huge expansion in the range and quality of products.

Within dairy we have seen the emergence of nut and oat milks but it is on the meat side where the changes have been most starting. Products such as the Beyond and Impossible Burgers offer virtually the taste and texture of meat but are entirely plant derived. Advances in fermentation technology will also increasingly allow products derived from fungi to faithfully replicate meat.

How it will influence the farming industry

Changing farming by changing type of inputs

The growth of plant-derived proteins will influence the farming industry in a number of ways. For a start it will lead to increased demand for a number of specific inputs which are used heavily in the current generation of plant-derived products with pea protein and oat among the prime examples. Moreover, the types of fungi best used in fermentation products are usually particular varieties which can require very specific conditions to thrive and the cultivation of these could rely increasingly on smart/precision farming techniques.

And reducing emissions…

On the flip-side, consumers' shifts away from animal protein on environmental grounds (mainly in developed markets) places an increasing onus on the agricultural industry to find ways of reducing its emissions as a means of winning back certain consumers.

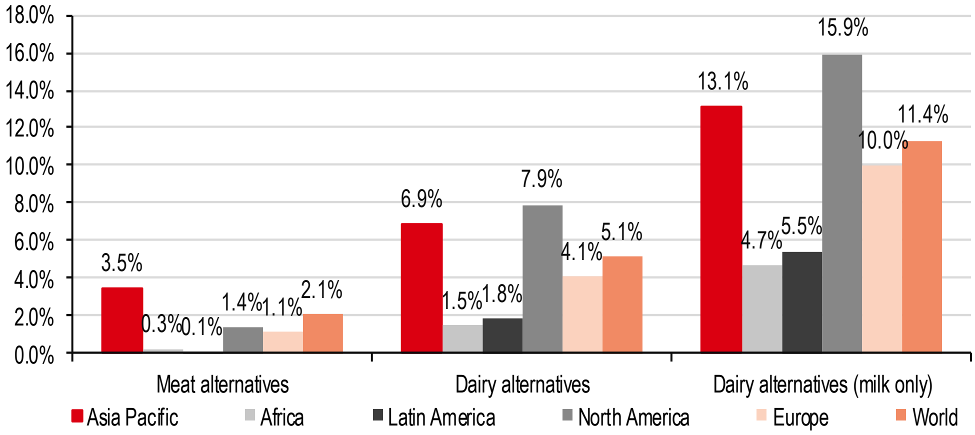
15 "Minnesota grain handler targeted in ransomware attack", Agweb, September 2021.
[2] "Cyberattack on food suplly followed years of warning", Politico, June 2021.

Alternative proteins could grow from USD40bn to USD140bn by 2030…

Current penetration and growth forecasts

As illustrated in the following chart, penetration of plant-based products is still very low with figures ranging from 0-3.5% for meat and around 5-16% for plant-based milks (and lower for plant-based dairy as a whole).

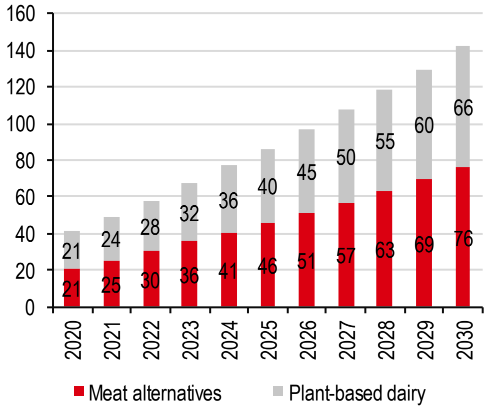
Chart 33. Global market share of plant-based products (2020)



Source: HSBC, Euromonitor

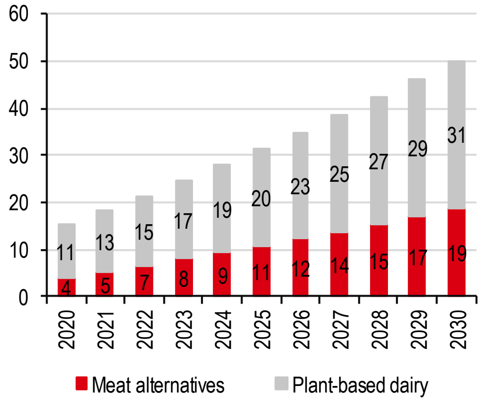
The potential growth of the industry is something we discussed in depth in our report on alternative proteins (see *Global alternative proteins, Big plate, small portion*, 29 November 2021). Based on a number of assumptions surrounding dietary changes and how this translates into the growth of alternative proteins, we see the global market growing from cUSD40bn today to around USD140bn by the end of the decade.

Chart 34. Estimated growth of alternative protein markets – global (USDbn)



Source: HSBC, Euromonitor

Chart 35. Estimated growth of alternative protein markets – N. America & Europe (USDbn)



Source: HSBC, Euromonitor

Will cost or processed nature deter consumers?

Main barriers to adoption

After a very strong 2019 and 2020 the alternative proteins category faced more difficult conditions in 2021, particularly on the meat side. Having tempted a lot of new consumers as the technology emerged, certain novel products found it hard to hold onto them while attracting additional converts also became tougher.

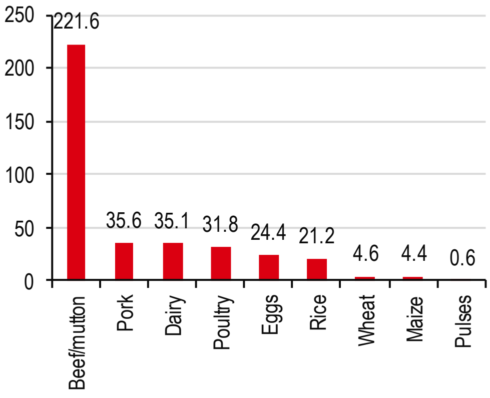
We attribute this to some of the drawbacks the category currently faces. For a start the products are generally much more expensive than the traditional animal derived proteins. While, particularly on the meat side, they face some resistance from their highly processed nature and the long lists of ingredients they contain. Fungi-derived fermentation products in particular offer the promise of much more concise ingredient lists.

The power to reduce CO_2 emissions

Up to 70% less CO2 than traditional dairy…

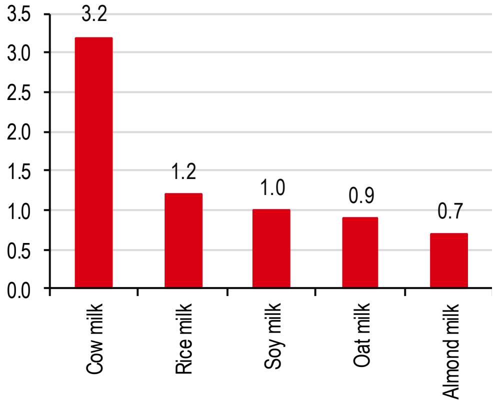
As outlined, one of the main attractions to consumers of plant-derived protein alternatives is their lower CO_2 footprint. Particularly on the meat side, the emissions savings through switching to plant-derived products are extremely large. Even in dairy, the average plant-based milk has CO_2 emissions c70% below that of traditional dairy

Chart 36. GHG intensity of different foods (CO_2 eq./kg protein)



Source: Our World in Data, Clark and Tilman 2017

Chart 37. GHG intensity of milk/milk substitutes (kgCO_2 eq./lit)



Source: BBC citing Poore & Nemecek, 2018.

Application of smart farming: Nitrogen fixation and the synthetic biology solution

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The fertiliser problem

Nitrogen is essential in the growth and development of plants and while c78% of the atmosphere is made up of nitrogen, that is not available in usable form to plants. Instead, plants rely heavily on external aids, in the form of fertilisers to meet their nitrogen requirements. This is done via the process of nitrogen fixation – which involves converting molecular nitrogen into a form which is easily utilisable by plants.

Nitrogen fertilisers responsible for c3% of global GHGs

Some plants, such as legumes can do this directly by forming a symbiotic relationship with nitrogen fixing bacteria that can convert atmospheric nitrogen directly for use by the plant. For most other plants though, the process has to be aided externally via the direct application of nitrogen fertilisers such as urea and ammonia. While fertiliser use increases crop productivity, there are pretty clear negative externalities with nitrogen fertilisers responsible for c3% of global GHG emissions.

The synbio solution

Synbio do not have a GHG footprint

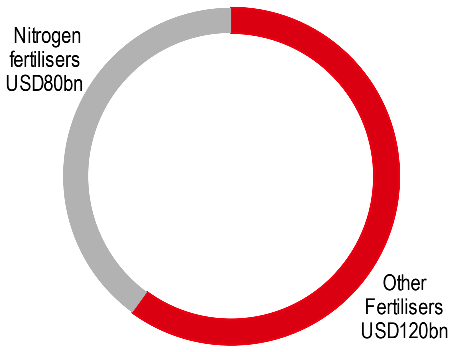
Synthetic biology platforms can engineer and design microbes that replicate the behaviour of naturally occurring nitrogen fixating microbes – as seen in legumes – and transfer the desired nutrient to any targeted crop – thus providing plants access to usable nitrogen and increasing crop yields. These genetically modified microbes outperform both organic microbes and industrial fertilisers. Unlike natural microbes, their influence is not limited to a specific type of crop. Also, unlike fertilisers, engineered microbes do not have a GHG footprint, do not utilise fossil fuels in the manufacturing process and do not cause run-off water pollution. The delivery mechanism is via seeds, with the engineered microbes coated onto seeds before they are sown.

Nitrogen fertiliser is worth USD80bn globally…

Potential market size

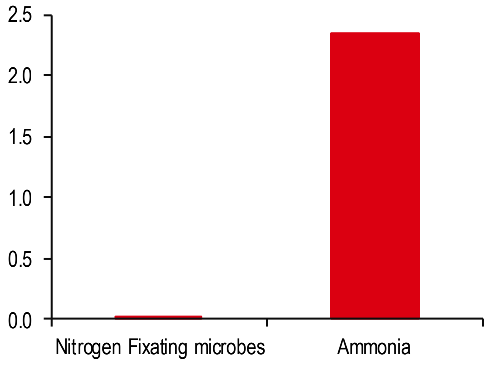
IHS values the global agricultural inputs market at over USD400bn annually, with half of this being the market for fertilisers and crop protection chemicals. Globally nitrogen fertilisers constitute a significant portion of the fertiliser industry and are estimated to be an USD80bn market.[16]

Chart 38. Global fertiliser industry market value (2020 – cUSD200bn)



Source: IHS Chemicals, HSBC

Chart 39. Carbon emission comparison: Ammonia vs nitrogen fixating microbes ($kgCO_2/kg$)



Source: IEA, Pivot Bio

Scaling synbio still an issue…

Key challenges

We believe that scaling might be the biggest hurdle for synbio nitrogen fertilisers as the majority of these projects are currently in the research phase and are yet to scale commercially. Also, despite not falling under the genetically modified (GM) food classification, there remains a possibility of poor consumer adoption since the process uses bioengineered organisms. Additionally, crops, soil conditions, weather, temperature, water availability, seed distribution and farming practices are significantly different from place to place. Hence designing microbes that can work across multiple different environments poses a big challenge.

Example 6: Who does synbio solutions?

The three major players currently working on synbio nitrogen fixation are Zymergen, DNA through its 50% stake in Joyn Bio and the unlisted Pivot Bio. While Joyn and ZY are still conducting field trials, Pivot Bio has successfully launched commercial products in the market and claims its microbial fertiliser is being used on more than 1mn acres of farmland. Pivot Bio is valued at cUSD2bn.[17]

16 IHS Chemical.
17 "Pivot Bio, a startup using microbes to replace synthetic fertilizer, raises $430 mln", Reuters, July 2021.

Applications of smart farming: Medications, genetics and GM

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Medicines to better Animal Health

Animal health medicine is a USD40bn+ market: Zoetis, one of the largest listed animal health companies, cites the size of the animal medicines and vaccines sector at approximately USD40bn. This total market is split between companion animal products (CAP, i.e. products for pets) and farm animal products (FAP, i.e. products for farm animals). Growth in both segments is expected to be quite robust with a number of companies and consultancies expecting multi-year industry growth of around 4-7%.

Vaccines & pain management

Farmers have long used medicines to improve the health and welfare of their herds. Consumer preferences and regulatory standards are becoming increasingly stringent with regards the treatment of animals in food production. Two areas that are growing particularly rapidly are vaccines (to reduce the need for antibiotics), and anaesthetics and analgesics (to help with pain management).

Usage, and drivers

Using vaccines is really an economic decision. In most scenarios a healthier herd should result in better economic outcomes. While there is concern about the level of antibiotics used in farm animal protein production (and the corresponding microbial resistance that can develop), relatively little regulation tends to exist around its usage. The regulatory burden tends to fall on suppliers (for example, the manufacturers of medicated feed) rather than farmers themselves. Anaesthetics and analgesics are however gaining direct regulatory traction as the ethicality of animal welfare comes to the fore.

Barriers to growth

The main barrier to increased take-up of these products in FAP is typically cost and awareness. In many parts of the world, farming remains relatively backyard and informal. As average farm sizes increase however, and production consolidates and becomes more technical, the trend is clearly towards a focus on greater efficiency and use of modern techniques which would include increased use of medicines.

Genetics to improve the efficiency of animal protein production

Market sizing is tough…

As there are very few public animal genetics companies, there are few sources with which to size the potential market for animal genetics. Arguably it is a subset of the total FAP market – since elite genetics can be applied across all species. Genus, one of the largest listed animal genetics companies, estimates that the cost of elite genetics is generally less than 5% of a farmer's costs.

What is the technology?

Companies breed for elite traits using genomic selection; using the genome of individual animals to inform breeding decisions. Breeding decisions are taken to maximise the prevalence and intensity of positive traits and vice versa. In practice this means elite animals exhibit higher feed conversion ratios (more protein per unit of feed), better health and lower emissions than non-elite animals.

How is it used?

The product itself depends on the specie and its characteristics. In porcine, for example, live elite boars and sows are actually flown to customers as the great grandparents for use in the customers' production pyramid. In bovine, semen straws prevail for use in artificial insemination. Therefore, while the method of delivery can vary the ultimate goal remains the same – to allow farmers to breed or hatch elite animals that exhibit favourable traits for farm animal protein production.

Going forward, gene editing may become more prevalent

Gene editing goes one step further than genomic selection. Using CRISPR technology, genes that already exist in a species' genome are turned on or off to achieve desired results. Genus, a listed animal genetics company, is already going through FDA approval for its porcine gene edit to counter Porcine Reproductive and Respiratory Syndrome virus (PRRS). PRRS is incurable and costs the pig farming industry approximately USD2bn annually therefore a gene edit which successfully confers resistance to this virus would be highly attractive from an economic and welfare point of view.

Meaningful contributions to farmer bottom lines

Elite genetics can have a major impact on farmer profitability. Feed, for example, is often one of the largest individual cost line items in a farmer P&L. Genus' elite porcine genetics, for example, have increased feed conversion ratios by 42% between 1970 and 2020 which is tremendous increase in what is typically a relatively low margin business.

Barriers to adoption…

Much like the use of medicines and vaccines, the barrier to increased utilisation of elite genetics is typically cost and awareness. In many parts of the world, farming remains relatively backyard and informal. As average farm sizes increase however, and production consolidates and becomes more technical, the trend is clearly towards a focus on greater efficiency which would include incorporating elite third party genetics into the production cycle.

Genetically Modified (GM) crops

GM is not a new technology

Genetic modification (GM) describes the manipulation of genetic material in organisms, this can be applied to crops at farm level, allowing them to perform certain functions or exhibit desirable traits. Although types of domestic modification can be seen occurring thousands of years ago, the development of modern GM has only been visible in the last 50 years or so. Crops are selected on traits such as insect, viral and herbicide resistance, fertility, nutritional value, medical benefits, climate adaption and crop yield.

Modifying traits of crops has bought benefits to both the economy, environment and society. They have been able to increase yields significantly, adapt to climate change and serve growing populations with both food and commodities such as cotton. They provide an opportunity to reduce pesticide use, minimising the impact on the environment. Additionally, the application to the energy sector remains a promising avenue for the GM crop. With rising biofuel adaptions, modified energy crops can assist the green transition to cleaner energy.

Worries of GM crops exist but play a role in sustainable farming…

However, challenges with the technology remain, and can hinder their adoption globally. Environmental hazards of GM crops include gaining a competitive advantage and reducing the prevalence of other species, reducing biodiversity. Safety to human health also poses a challenge due to lack of large-scale studies and the risk of unintended consequences to health, such as antibiotic resistance. Although these challenges remain, GM crops have a role to play in the transition to more sustainable farming.

Vertical farming

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Vertical farming (aka indoor farming) is the practice of growing plants/crops in vertically stacked layers in warehouse, containers, rooftops or even skyscrapers. These farming techniques stimulate the plant growing processes through artificial control of lights. The plants are grown without soil and use 95% less water. Moreover, these farming techniques do not use pesticides as the problem of weeds/insects is non-existent in a controlled environment. Fertilizer/nutrient use are reduced by as much as 60%. Given the proximity to demand centres, vertical farming can save significant costs on cold storage and transportation. The cost of transportation is typically much higher for horticulture like lettuce (c30% of cost) than for grains (c10-15% of the cost).

Vertical farms have an environmental benefit as they reduce stress on limited resources such as land and water. As per Aerofarms, a start-up company, vertical farming in one acre of land can produce as much food as a 390-acre traditional farm does. The produce can be grown in urban areas on low cost real estate such as warehouses, rooftops etc. Hence, this concept is likely to see more adoption in regions that are short of arable land like the Middle East and Singapore and also for products such as lettuce and vegetables for which the shelf life is limited. The success of vertical farming, however, depends on overcoming cost and technological barriers.

Leafy greens in vertical farming

Technology and cost economics are the key barriers

Currently, lettuce and other leafy greens are the most popularly grown plants in vertical farms as they are easy to grow. The technology for indoor production of berries, aubergines and other fruits and vegetables in the vertical, are in the developmental stage. Further, offsetting the benefits are comparatively higher set-up costs and an increase in operating expenses. Electricity to power up LEDs is the single largest operating cost. Higher operating and capex costs relative to conventional farming makes the model viable only in specific cases that are catering to niche markets where the produce can be sold at a premium and there is a need for reliable supply, for example - supply to airlines and restaurants. Aero farms took 9 years to make meagre profits, according to Forbes, while many vertical farming companies have also closed their business due to high costs involved. On the bright side, investment interest in the space has picked up recently that could foster new technologies and help bring down the costs.

Vertical farming expected to be worth USD20bn by 2026

Market size and recent deals

BIS research estimates the market size of vertical farming at USD5.5bn in 2020 and expects to reach a CAGR of 24% through 2026 to reach nearly USD20bn. High growth potential and its sustainability credentials have attracted growing investments in the space. According to Pitchbook, cUSD1.9bn was invested in vertical farming start-up companies in 2020, almost 3x higher than 2019 levels. Google Ventures invested USD90m in Bowery Farming in December 2018, which later in May 2021, raised USD300m of funding at a valuation of USD2.3bn. Softbank invested USD200m in a start-up called Plenty in 2017. Later in Jan 2022, Plenty had raised USD400m and also signed a supply deal with Walmart that also participated in the funding. In December 2021, Infarm, based in Europe, secured USD200m in private equity raising that puts the valuation at over USD1bn.

There are a handful of listed companies that develop and operate vertical farms and/or provide the technology and equipment needed to develop the farms. Hydrofarm Holdings, CubicFarm Systems, Village Farms International, GrowGeneration Corp, AppHarvest are the notable names in the space. Aerofarms was supposed to be listed through the SPAC route in 2021 at a valuation of USD1.2bn, but the plan was later dropped.

Example 7: Faster crop cycles with indoor farming[18]

Local Bounti is a US listed Climate Environment Agriculture (CEA) company which uses indoor farming technologies to produce vegetables and greens. It uses technology called Stack & Flow which it has said combines the best of vertical farming with the best of horizontal farming (e.g. greenhouse farming). This enables it to reduce the crop cycle turnaround in its indoor farms.

For example, using this technology, in combination with AI, automation and genetics innovations, it can produce leafy greens in 16 days as opposed to 24 days using traditional greenhouses and 24-30 days for vertical farming alone.

Local Bounti has also said that living lettuce can be grown using its technology in 28 days as opposed to 50+ days using traditional greenhouses and living herbs can be grown in 16-21 days with its technology verses 38 days and 35-45 days in traditional greenhouses and the traditional vertical farm. This combination of vertical farming and greenhouse hybrid and other hydroponic techniques, enables it to increase productivity on its farms, and with better unit economics verses traditional outdoor farming as outlined by the above crop cycles durations.

18 Illustration of vertical farming applications for smarter farming from our Disruptive Technology team.

Circular economy

Creating a closed loop to reduce waste and resource inputs

The standard model for an economy is a linear one, where raw materials are extracted from the earth, processed into goods which are used, and then disposed of as waste. However, the concept of a circular economy is gaining traction. A circular economy is a closed loop in value chains where materials intended for waste are reused/recycled to create new products, minimising resource inputs, while reducing emissions. This concept is gaining traction due to growing populations in the face of finite resources, and the growing focus on sustainable living. A circular economy has the potential to address key sustainability challenges, and improves our quality of life.

Agriculture uses 70% of global freshwater

The agricultural industry is responsible for roughly 70% of global water use, creating a strain on water resources. This is especially a concern in emerging markets, where the market particularly dominates. Utilising a circular system can assist in reducing this number, and the potential to reuse irrigation water. This would not only save water, but if treated properly, can provide valuable nutrients. The same applies to emissions, where altering the value chain to make it more circular could create efficiencies which would ultimately minimise overall emissions generation from the sector.

Utilising waste for fertiliser and biofuels

Waste in agriculture takes the form of organic and inorganic waste. Within this category of waste in agriculture is food waste, a third of which is wasted each year. This waste contributes to the inefficiencies of the agricultural sector, ultimately exacerbating land management, water use and emissions problems. Further, in a more circular economy, this waste can be deployed for other resources, for example as a source of fertiliser or as a source of energy via the use of biofuels. This can be used for heat, electricity and transportation, and reduces reliance on fossil fuels.

The key to making sure resources such as water aren't wasted through the agricultural supply chain is to encourage more circularity in the industry. This can be somewhat addressed in the first stage in the supply chain. Precision farming and Hydroponics are two developments the industry can adopt to help achieve this for the value chain and a more sustainable approach to agriculture:

- **Precision agriculture** – This is the use of technology, research and big data to increase crop yields while limiting the levels of inputs to ensure the correct amount of substances are used in the right areas and times. Inputs such as water, pesticides and fertilisers can be limited and directed to where they are required most. This reduces the impact agriculture has on the environment via its water use, emissions and waste, as well as pollution via the over use of harmful substances.
- **Hydroponics** – A type of agriculture that doesn't require soil, whereby plants are grown in water and provided with the exact amount and type of nutrients required. Modern hydroponics utilise data and automation to increase yields by taking control of which conditions the crop grows in. This is sustainable and reduces waste via managed water usage and provides less risk of pollution elsewhere. However, this type of farming has its risks. These include large amounts of energy usage (due to it typically occurring indoors) and the economic cost incurred for the infrastructure required, therefore, not suitable for smaller farms with lower budgets. Coupled with hydroponics is **aquaponics**, which varies by the use of fish to provide a natural source of nutrients instead of adding the fertilisers directly to the system. The plants naturally filter the water and create a circular system benefiting both plant and fish.

See our reports on the circular economy theme for more information: *Waste less, grow more (September 2019)*, *The European Green Deal (March 2020)*, *ESG Matters (February 2021)* and the *Circular economy round up (December 2019)*.

Example 8: Upward Farms and aquaponics

In the United States, Upward Farms have been developing aquaponics techniques alongside vertical farming to raise both fish and plants in its own ecosystem. Its crops are free from synthetic chemicals, such as pesticides and fertilisers and are USDA Certified Organic. The fish it produces are free from hormones, antibiotics and mercury.

In January 2022, the company announced its plans to add the world's largest vertical farming facility in Pennsylvania, United States, to be completed and operational by 2023. The facility will provide both fish and microgreens, by using the organic waste from the fish to provide fertiliser to the greens[19].

19 'Upward Farms Announces World's Largest Indoor Vertical Farm', Business Wire, January 18 2022

Smart farming opportunities and impacts in banking

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Agriculture considered capital intensive by lenders

Another angle to think about in this chapter, though while not innovation related directly, is funding, which is important for new, smarter farming technologies. Technological change in any sector can result in both opportunities and challenges for the banking sector. A potential step-up in productivity and the related need for upfront capex to facilitate the adoption of new equipment will require credit. Provided the new technology is viable, this should lead to a value-creating lending opportunity for the banking sector.

In developed markets, the significance of the agricultural sector has been diminishing in importance for the banking sector. ECB data show that combined agriculture, forestry and fishing represent just 4.2% of EU bank loan books. Much of this can be explained by the shrinking share that agriculture typically contributes to post-industrialised economies. Moreover, lenders have tended to view agriculture as capital intensive, rather cyclical and with unhelpful correlation in their credit portfolio i.e. farmers tend to have bad harvests at the same time. As a result, banks have focused on other more growth orientated sectors of the economy.

Why smart farming could fuel lending in agri sector

Smart farming has the capacity to potentially reinvigorate lending to the agricultural sector. The improvement in efficiency and increase in yields is a key element. In addition, the lower variability in harvests should in theory reduce the risk profile of lending into the smart farming sector versus conventional farming. The related upfront investment in hardware at this stage is difficult to quantify. However, improved tracking and real-time data should drive better predictability of outputs and yields. Together with greater control and monitoring of key inputs (e.g. fertiliser, water, pesticides etc.), this should strengthen the credit worthiness of tech-savvy farmers willing to transition into these new technologies. Further down the value chain, greater automation in the downstream transport and logistics of agricultural products may improve the cost structures and risk management for banks that provide trade and commodity finance.

Banks with strong microfinancing could help smaller farms

The economies of scale associated with large consolidated farms may allow greater financial resources to adopt new technologies, install the necessary hardware, and implement the big data analytics to enhance crop yields. However, the use of smart farming is not limited to large-scale agricultural operations. Indeed, in certain areas the new technologies may eventually make smaller scaler farming operations more viable and competitive. Indeed, the productivity gap is wider at the smaller end of producers, and therefore smart farming could drive a larger upward in efficiency and yields. As a result, we would expect banks with strong microfinance capabilities to potentially benefit, particularly in geographies with large but fragmented agrarian sectors.

Could help quantify GHGs on loan books?

Alongside the broader environmental and social benefits of smart-farming, the improved data collection will support the banking sector's ongoing efforts to better quantifying GHG emissions of their loan books. Issues around data quality and availability are particularly applicable in sectors that have historically been less data-centric such as agriculture. Indeed, the benefits to the carbon footprint of the overall loan book from say arable farming and sustainable forestry may become better quantified and recognised by bank stakeholders, thanks to the hard data provided by smart farming.

China digital agriculture

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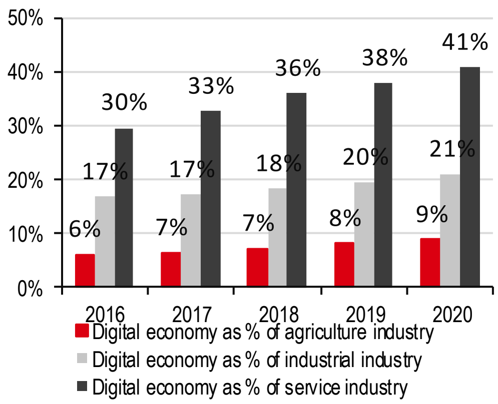
Digital agriculture is still in the beginning stage of development in China, with the digital economy contributing merely 9% to China's agriculture industry in 2020, versus 21% and 41% for industrial and service industries (the China Academy of Information and Communications Technology (CAICT), 2021). The Chinese government has been supportive of the rollout of digital agriculture and China internet companies play an important role in facilitating this process especially in developing the necessary technology. This includes providing access to stable online ***sales channels,*** assisting in optimising ***production*** using data analysis, and improving ***supply chains*** which helps ensure food safety as well as increase farmers income.

Technology adoption in agriculture is still low in China:
Low technology adoption leads to low digitalisation level

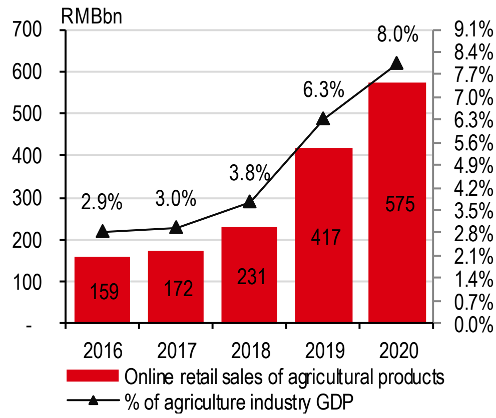
Digitalisation adoption is low in both production procedure and sales channel in the China agriculture industry, this is evidenced in online penetration of agricultural sales, which was 8% in 2020, versus 25% for all physical goods sales. We think there are a few reasons for this.

Chart 40. Digitalisation ratio of agriculture was 9% in China in 2020



Source: CAICT, 2021

Chart 41. 8% of agriculture GDP is from online agriculture product sales



Source: NBS

What are the major bottlenecks of technology adoption?

Fragmentations in farms, skill shortages and lack of data remain key issues

A fragmented industry: In short, small farmers dominate agriculture production in China. According to the 3rd agriculture consensus published by the National Bureau of Statistics, 98% of the agricultural businesses in China is owned by small farmers, who operate 70% of the planted area in China. The entry barrier and initial cost for adopting digital technologies are high for small farmers, who also do not enjoy economics of sales on a standalone basis, making it difficult to improve their willingness to invest and adopt new technologies.

Lack of talent: Again as the majority of the land is planted by small and individual farmers, there is a lack of professional talents to adopt digital agricultural. In fact, c.70% of China's farmers graduate from middle school and below, and their farming largely depends on experience rather than knowledge (*China Youth Online*, 2019). This makes it challenging for Chinese farmers to understand the value of digitalisation and they probably also lack the ability to master the technologies.

Difficulties in collecting and analysing data: Smart production requires the collection of a large amount of relevant data and the real-time response of data accumulation. However, information infrastructures of agriculture production are not widely available at this stage, and the efficiency is low due to a lack of qualified land, machines and other facilities (*China Farmer Website*, 2021).

But government is supportive

Government support is there…

Digital agriculture is in line with the Chinese government's goal of modernising agriculture industry and rural area revitalization. The central government has released several policies to push the technology development in the industry, including:

- In May 2019, the central government published its outline for its digital rural area development strategy (数字乡村发展战略纲要), focusing on building the rural infrastructure of ecommerce logistics, remote sensing satellites and IoT.
- In Feb 2022, the central government published the "14th five year plan" for agriculture and rural area modernisation(国务院关于印发"十四五"推进农业农村现代化规划的通知), where we see a great emphasis on technology applications in the whole industry value chain of the agriculture industry, including supply chain upgrades, standardised production, smart monitoring systems and smart farming.

Smart production in China

China Internet companies offer agriculture technologies

Internet companies have facilitated producers and farmers with their technologies and tools in order to improve production efficiency and reduce production costs.

- **Alibaba's** cloud business unit **AliCloud** offers AIoT (Artificial Intelligence of Things) solutions that are tailored for the agriculture industry. By leveraging Internet of Things (IoT) sensing technology, AliCloud collects full data and information from farm land, crops and the environment, then it uses big data analytics to optimise decision making, standardise planting procedures and to achieve scale production. The technology-empowered production process also ensures better quality of agricultural products.
- **Pinduoduo** promotes smart agri-tech using advanced agricultural technologies and devices. For example,
  - **Pinduoduo** has partnered with the Chinese Academy of Engineering by introducing a plan for co-locating late-maturing mandarin oranges alongside lemons that are well-suited to deep mountain gorge conditions, in the Nujiang River project. (Company ESG Report, 2020)
  - **Pinduoduo** promotes drip irrigation and remote monitoring devices. In some pilot projects involved in growing orange trees, 15% less fertilizer and 30% less labour is required, which increases farmers' earning per acre. (Company ESG Report, 2020)
  - **Pinduoduo** worked with the Yunnan Institute of Tropical Cash Crops on selecting high-quality coffee varieties suitable for the altitude and latitude in test fields, in the Baoshan project. (Company ESG Report, 2020)
- **JD Technology(JDT)** developed a mini programme for agricultural machinery rent services, helping to improve the utilisation rate of agricultural machinery in Guanghan (a city in Sichuan province) by 60% in 2020 (Company Sustainability Report for 2018-2020). **JD Fresh**'s "JD Running Chicken" (京东跑步鸡) project uses scientific methods to raise free range chicken. The project has made sure that breed density is 2-3x that of general free-range raised chicken, and it uses a smart environment monitoring system for the actual environment 7x24h (*Sohu news*, 2020).
- **Tencent's iGrow system,** an AI planting solution, helps reduce labour costs by 20-25% and heating costs by 30-40%. It carried out pilots of iGrow in Heilongjiang, Liaoning, Shandong and other major agricultural provinces, helping farmers increase their revenue. **Nano T-Block**, an advanced data centre developed by Tencent, has been deployed in Inner Mongolia's Ulan Buhe Desert. It can perform real-time monitoring of surrounding environmental data, accurately adjusting irrigation levels according to demands of the soil and accelerating its conversion to farmland (*QQ news*, 2020).

China supply chain tech

Enhanced supply chain infrastructures

- **Alibaba's initiatives**: Alibaba is committed to investing in supply chain infrastructures - Alibaba has built 1,000 digital agricultural bases, 5 digitalised large scale producing area warehouses, as well as 1,000+ Cainiao county level express delivery centres and many city warehouses across the country. In addition, Alibaba has both online and offline sales channels, including Taobao/Tmall/Freshippo (online) and RT-Mart stores (offline), to support agricultural products sales. These channels helped to deliver 1mn tonnes weight of fresh produce to end customers in 2020. The company has set a target to help build eight "RMB1bn branded agricultural industry belts" and 100 county originated ecological produce brands in 3 years (Alibaba CSR report for 2020-2021).
- **Pinduoduo's marketplace produce selling model streamlines the sales channels:** In the traditional distribution model, wholesalers and distributors share a good portion of the value within the supply chain and sometimes it may even be bigger than the farmers' share. Under Pinduoduo's model, farmers are connected to consumers directly. By removing the intermediaries, farmers can offer prices that are lower than consumers are used to paying and farmers can also enjoy higher profitability in many cases (Company ESG Report, 2020).
- **JD** uses data collected from its ecommerce platforms and logistics services to help farmers in Guanghan (of Sichuan province) to understand consumers' demands and identify popular products in the region. As a result, many producers enjoyed higher growth in product sales. **JD**'s financing service – "Jingxin Zhu Nong" (京心助农) helped 1.3m producers make 300m units of agricultural products by Oct 2020. These sales covered over 800 agriculture industry belts, ~2,100 poverty counties and 500,000 farmers (Company Sustainability Report for 2018-2020).

Alibaba and PDD have done more so far

Other digital agriculture companies in China include Nxin (农信互联) and TerraQuanta (大地量子), both are relatively small private companies. One provides supply chain services for swine rising and the other focuses on spatial big data SaaS/API and SDK for different industries including agriculture. Within the China Internet space, we think Alibaba and PDD take the lead in the agriculture digital space; this is particularly true from an online sales channel standpoint. Even though penetration remains low at c8% in 2020, these two e-commerce platforms account for the bulk of online agricultural sales. From a technology provider standpoint, Alibaba likely takes the lead given its dominance in the Cloud and blockchain technology. PDD sets agricultural investment as a key priority for the company. Last year, PDD announced its "RMB10bn Agriculture Initiative", which will go into improving agricultural technology and efficiency but at this stage, it is unclear what type of projects and investment PDD will be making.

Regulatory frameworks

- Like other sectors in becoming more friendly to the environment…
- …The farming and agriculture sector will need similar support in the longer run
- Today we see COP26 establishing deliverables for the sector, as well as regional regulations emerging to support smarter farms locally

Assisting the transition…

Government and institutional policy support crucial in other sectors…

It's likely that the transition to smarter, more sustainable farming could require significant investment and assistance by governments and other institutions, similar to other sector technology transitions such as within heavy goods vehicles or shipping. See our "Towards low carbon trucks" (26 May 2020) and "Towards low carbon shipping" (10 February 2021) reports.

In this chapter we highlight key developments in the latest United Nations Climate Change Conference and outline legislations relating to agricultural development across selected regions globally.

What are the COP26 agricultural deliverables?

COP26 developments in agriculture

The 26th United Nations Climate Change Conference (COP26), which took place in Glasgow from 31 October to 13 November 2021, saw developments aimed at agriculture and its impact on the environment. Although COP26 didn't have a day dedicated solely to agriculture, some deliverables were launched. The table below summarises these developments.

Table 3. COP26 agriculture deliverables summary

COP26 agriculture deliverable	Summary
The Glasgow Leaders' Declaration on Forest and Land Use	Representing over 90% of global forests, and signed by 137 countries. Aiming to emphasise the roles of forests, biodiversity and sustainable land use to meet Sustainable Development Goals (SDGs). Projects include conservation and restoration of forests.
The Glasgow Innovation Breakthrough in Agriculture	Aims to make smart and sustainable agriculture practises, to be widely adopted by farmers globally by 2030.
COP26 IPLC Forest Tenure Joint Donor Statement	To support the forest tenure rights of indigenous people and local communities. Includes the UK, Germany, Norway, US, Netherlands and 18 philanthropic donors pledging EUR1.7 billion.
The Policy Action Agenda for Transition to Sustainable Food and Agriculture	To support the transition to sustainable agriculture by repurposing public policies, endorsed by 16 ministries of agriculture globally.
The Global Action Agenda for Innovation in Agriculture	To increase investment in agriculture research and innovation, focusing on climate resilient, low emissions solutions.
Launch of the Agriculture Innovation Mission for Climate (AIM4C)	The United States and the UAE, alongside 31 other countries launched the AIM for climate programme, which aims to mobilise investment in climate-smart agriculture and food system innovation over the next 5 years. Currently, the programme has gained USD4 billion in investment.
Koronivia Joint Working Group on Agriculture	Focusing on the importance of soil management and the sustainable production of animal proteins in climate-resilient food systems – decision expected at COP27..

Source: HSBC, United Nations, UK Government, E3G, USDA

Regional legislations

United Kingdom

Push back in Northern Ireland…

Northern Ireland ministers have voted to amend the nation's **Climate Change Bill** to a legally binding net emissions reduction target of 100% by 2050. However, the agriculture minister is set to push for an exemption stating that it is too challenging to achieve such a target in the sector[20].

Farmers incentives to improve in UK…

In 2020, The **Agriculture Bill** was introduced in the UK, and included measures to avoid farmers being incentivised to over-produce and costing the environment while doing so. Instead, they are being financially rewarded to improve air and water quality, soil health and animal welfare. The Bill hopes to increase farmer flexibility to climate impacts and invest in low-carbon crops and regenerative methods.

European Union

CAP to be adopted in 2023 by EU…

The **European Climate Law** writes into law the European Green Deal goals, to achieve net zero greenhouse gas emissions by 2050 for EU countries. The **Common Agricultural Policy (CAP)** is the EU's set of laws regarding agriculture and forestry aligning with the European Green Deal. In December 2021, the CAP underwent a reform to be adopted in 2023. Strategic recommendations include EU level targets on the use and risk of pesticides, sales of antimicrobials, nutrient loss, area under organic farming, high diversity landscape features and access to fast broadband internet[21].

EU Farm to Fork strategy to reduce negative impacts from pesticides and fertilisers and antimicrobials

The EU's **Farm to Fork strategy**, under the European Green Deal, aims to ensure sustainability, quality of, access to, and affordability of food in Europe and beyond. The strategy will achieve this by reducing the use of pesticides (*50% reduction of chemical and hazardous pesticides by 2030*), fertilisers (*at least 20% by 2030*) and the sales of antimicrobials (*50% reduction by 2030*). Additionally, achieve 25% of total farmland to be under organic farming by 2030, to enhance environmentally-friendly practise. See *The European Green Deal (May 2020)* for more information.

United States

US targets clean water, and financial compensation for improving soil and water

The **National Environmental Policy Act (NEPA)** requires that the environmental significance be assessed on all federal projects, including agricultural irrigation, and an environmental impact statement (EIS) to assess this. Another significant agricultural environmental law is the **Clean Water Act (CWA)**, which governs pollution navigation and covers pesticides and fertilisers across US waterways. Additionally, conservation programmes in the US include the **Conservation Reserve Program (CRP),** whereby producers can receive financial compensation for dedicating spaces to reduce soil erosion, improving water quality and enhancing habitats.

South Africa

SA schemes to support landowners…

To promote agriculture, South Africa introduced the **Land Distribution for Agricultural Development Programme** and the **Comprehensive Agricultural Support Programme (CASP)**. These schemes support disadvantaged individuals and landowners to obtain land and facilitate farming, providing support in areas such as finance, information, technology, training and infrastructure.

China

Mainland China to protecting land, machinery subsidy and more…

In 2013, the government issued the **Finance Management Measures for Agricultural Production and Development (Finance Management Measures).** The latest revision in 2020 includes support for agriculture by focusing on protecting cultivated land resources, subsides for machinery and innovation projects and green development via increasing efficiency and reducing water and chemical fertiliser use.

20 'Ireland votes for legally binding 2050 net-zero target, but agriculture may be exempt', Edie, February 2022
21 'CAP strategic plans', European Commission, accessed February 2022

Brazil various funding mechanisms…

Brazil

Brazil's **National Rural Credit System** provides credit to producers at preferential interest rates, in addition to credit for marketing, working capital and investments.

Government support of farmers in India for more freedom

India

In September 2020, three agriculture regulations were passed by the government. The first is **The Essential Commodities (Amendment) Act**, which creates greater freedom to farmers to produce, hold, distribute and supply produce, providing the opportunity for investments in cold storage and facilities. The second is **The Farmers' Produce Trade and Commerce (Promotion & Facilitation) Act**, which removes restrictions on trade, and provides greater freedom of choice, promoting competitive, efficient prices. Finally, **The Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Act**, which aims to protect and empower farmers to interact with other key stakeholders including retailers, to produce at a mutually agreed price. Additionally, allowing greater access to modern technology and better quality inputs.

Notes

Notes

Disclosure appendix

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The target price is based on the analyst's assessment of the stock's actual current value, although we expect it to take six to 12 months for the market price to reflect this. When the target price is more than 20% above the current share price, the stock will be classified as a Buy; when it is between 5% and 20% above the current share price, the stock may be classified as a Buy or a Hold; when it is between 5% below and 5% above the current share price, the stock will be classified as a Hold; when it is between 5% and 20% below the current share price, the stock may be classified as a Hold or a Reduce; and when it is more than 20% below the current share price, the stock will be classified as a Reduce.

Our ratings are re-calibrated against these bands at the time of any 'material change' (initiation or resumption of coverage, change in target price or estimates).

Upside/Downside is the percentage difference between the target price and the share price.

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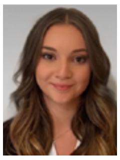

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