Invesco

Appetite for change: food, ESG and the nexus of nature

Part III: Agtech and the future of farming

Contents

Invesco is not affililated with Maria Lettini of FAIRR or Jonathan Webb of AppHarvest.

Authors

Glen Yelton
Head of ESG Client Strategies North America, Invesco

Glen Yelton is Invesco's Head of ESG Client Strategies in North America. He was previously a Director of ESG and Impact Investing at OppenheimerFunds and also held ESG-related and research-related roles at a number of investment, data and ratings businesses. As well as helping build strategies, he works with Invesco's product teams to identify new ESG opportunities.

Jonathan Webb
CEO, AppHarvest

Jonathan Webb is the founder and CEO of AppHarvest. Encouraged by investors, advisers and politicians, he established the company in 2017 with the goal of turning Appalachia into America's agtech capital. He previously worked on a major solar project with the US Department of Defense in Washington. He has a degree in business from the University of East Kentucky.

Maria Lettini
Executive Director, FAIRR

Maria Lettini is Executive Director of FAIRR. She was previously Head of the Americas for the Principles for Responsible Investment (PRI) and also worked for financial institutions including JP Morgan and Deutsche Bank. She studied environment, politics and globalisation at King's College London and business, Latin American studies and Spanish at San Diego State University.

Conor Hartnett
ESG Client Strategies Manager, EMEA, Invesco

Conor Hartnett is Invesco's ESG Client Strategies Manager in EMEA. He helps the business integrate ESG issues into mainstream investment processes, particularly with a view to mitigating and adapting to climate change. He previously worked for CDP (formerly the Climate Disclosure Project), including serving as its Senior Project Officer for Capital Markets.

Dr Henning Stein
Global Head of Thought Leadership and Market Strategy, Invesco

Dr Henning Stein is Invesco's Global Head of Thought Leadership. He joined Invesco in 2016 from Deutsche Asset Management, where he led EMEA institutional and retail marketing and chaired the company's academic foundation. He holds a PhD in business and strategy from the University of Cambridge and is a Fellow at Cambridge Judge Business School.

1

Executive summary

- Many longstanding agricultural policies and practices are increasingly seen as not only unsustainable but detrimental to the future of the planet and its inhabitants.
- In tandem, with the global population expected to reach almost 10 billion by 2050 and more than 11 billion by 2100, they are highly unlikely to meet rising demand for food.
- Agtech – agricultural technology – has emerged as a key driver of efforts to move away from a heavily industrialized model and embrace the idea of "farming smarter".
- While the sector attracted less than $100 million in investment in 2010, a single agtech company – AppHarvest – raised $475 million when it listed on the Nasdaq in 2020.
- As a contributor to collective survival, agtech serves as compelling example of technology's frequently overlooked capacity to improve lives on a substantial scale.
- As such, it also illustrates the importance of investors channeling capital into genuinely disruptive ideas that might otherwise fail to fulfil their enormous potential.
- Continued innovation in this space is likely to be vital in overcoming the long-term failings of the 20th century's Green Revolution and ushering in an Ever-Green Revolution.

2

Introduction

"

The burgeoning expectation is that this arena will make an enduring difference on a vast scale.

In the first paper in this series, Lessons from the COVID Crisis, we explained how longstanding policies and practices around food production have come to threaten the planet[1]. In the second, The search for sustainability, we explored how the incorporation of environmental, social and governance (ESG) considerations is increasingly encouraging more sustainable approaches that should help save the planet[2].

Extending this positive trajectory, we now look to the future. Specifically, we examine the potentially pivotal role of agtech – agricultural technology – in delivering lasting, far-reaching, beneficial change.

The idea of "farming smarter" has gained significant momentum in recent years. Advances such as big data, artificial intelligence (AI) and robotics are showing what can be done when cutting-edge thinking is used in concert with nature rather than to its detriment.

Agtech's rise has been so swift that there is mounting evidence to suggest that the sector is already nearing maturity – or has even attained it. According to research by AgFunder, investment in farmtech – the agtech sub-sector that covers areas such as crop inputs, machinery, devices, software, analytics and logistics – went up by 41% year-on-year in 2020, with a total of around $7.9 billion in funding[3].

Many of the businesses now seeking a market listing, particularly via the SPAC (special purpose acquisition company) route, are not showcasing their current financial strength: they are instead emphasizing their likely impact. This underlines the burgeoning expectation that this arena will make an enduring difference on a vast scale.

We commence our analysis by reflecting on agtech's crisis-driven origins, placing the phenomenon in the context of the long-term failings of the Green Revolution. We then make the case for an Ever-Green Revolution, taking a closer look at some of the key innovations in this sector and how they support an overarching dynamic of radical yet necessary disruption.

Finally, we offer insights from several figures at the forefront of this field – including Jonathan Webb, founder and CEO of AppHarvest. Webb firmly believes that businesses must take the lead in dramatically reorienting the course of food production. As responsible investors who understand both the grave threats and the tremendous opportunities posed by the ongoing quest to feed humanity, we share his vision of "cultivating the future".

3

Roots

3.1. Resources and revolutions

Like many spheres of innovation, agtech has its roots in crisis. Its emergence stemmed from the need to address numerous trends associated with food security, population growth arguably foremost among them. It is in many ways a state-of-the-art response to the threat of resource scarcity.

This threat has been recognized for hundreds of years. It was first famously expressed in Thomas Malthus's An Essay on the Principle of Population, published at the end of the 18th century[4]. Yet it was perhaps not until the aftermath of World War II that a genuine answer was at last thought to have been identified.

What became known as the Green Revolution began in Mexico in the latter half of the 1940s. By creating novel varieties of wheat capable of producing spectacularly abundant yields, pioneering American scientist Norman Borlaug rapidly turned a national shortage of cereal crops into an immense surplus.

The revolution spread around much of the world during the ensuing decades, staving off famine in many countries and exerting a huge and lingering influence on agricultural methods. Particularly from the 1980s onwards, it was prolonged by the use of GMO (genetically modified organism) crops – an innovation credited with boosting yields, upping profits and reducing pesticide use[5].

Today, though, the revolution appears to have run its course. As outlined in the first two papers in this series, many prevailing aspects of food production are no longer part of the solution: they are part of the problem. Most cultivatable land is used for crops to feed livestock or for processed food. Factory farming remains a deeply worrying norm. What was once a newfound reliance on fertilizers and irrigation has become a damaging overreliance.

Above all, the scourge of hunger is still to be eradicated. Hopes of eliminating it by 2050 are unlikely to be fulfilled, with the Food and Agriculture Organization (FAO) of the United Nations (UN) warning that "the current rate of progress will not be enough"[6]. The Global Hunger Index describes the situation as "serious" in 40 nations and "alarming" in 11[7]. An estimated 690 million people worldwide are undernourished[8].

Both the urgency of the issue and the brightest prospect in terms of addressing it are encapsulated in the second of the UN's 17 Sustainable Development Goals: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture." An Ever-Green Revolution is now clearly imperative, and agtech is likely to be vital to its realization.

Billions more mouths to feed

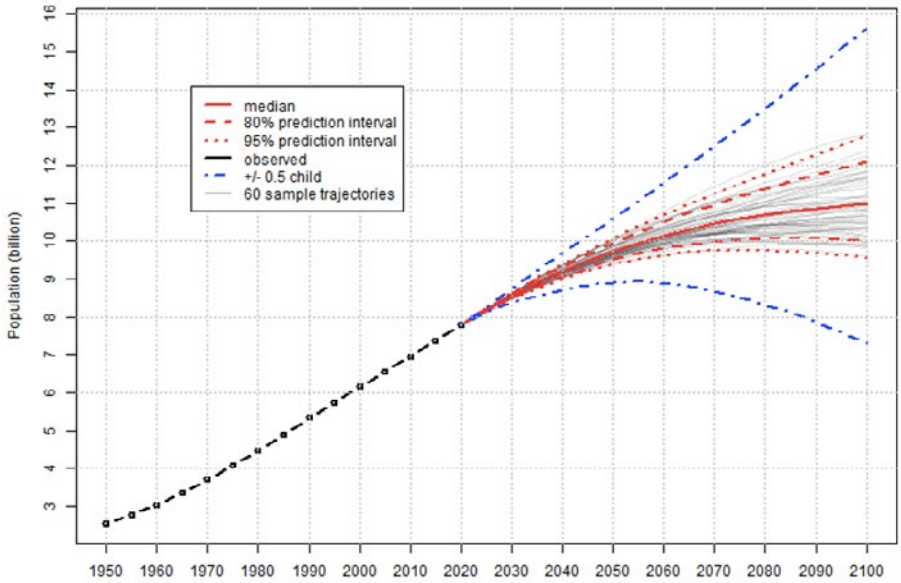
In 1950, as the Green Revolution was gathering pace, the global population was around 2.5 billion. Today it stands at approximately 7.8 billion. The UN predicts that it will reach 9.8 billion in 2050 and 11.2 billion by the end of the century[9].

Conventional farming methods are unlikely to meet rising demand for food as this trend continues. Agtech aims to provide a solution by steering agriculture out of the industrial era and into the digital age.

“

The Green Revolution appears to have run its course. Many prevailing aspects of food production are no longer part of the solution: they are part of the problem.

Population growth – past, present and likely future



Source: : FAIRR: FAIRR Protein Producer Index, 2021

3.2. Existential threats and industrial-era thinking

The devastating possibility of famine was viewed largely in isolation when the Green Revolution got under way. More than 70 years later, in the face of the pressing need for an Ever-Green Revolution, we appreciate that it is just one component of a complex web of highly interconnected risks.

As discussed in the first paper in this series, food crises represent a key element of the nexus of nature – an intricate network of existential threats confronting the planet and its inhabitants. Uniting all these is humanity’s misguided belief that it has gained mastery over the natural realm.

Climate change sits at the nexus’s heart. It is closely linked to issues such as urbanization, industrialization and loss of arable land – all of which, in turn, are closely linked to dangerously outmoded agricultural approaches that take insufficient account of the damage they are wreaking and the pervasiveness of its repercussions.

Consider, for example, greenhouse gas (GHG) emissions. Around 15% of all anthropogenic GHGs come from livestock[10]. Globally, cattle alone emit enough GHGs to rank alongside the most polluting nations – rivalling the US and trailing only China. Forestry, rice cultivation and switches in land use are all substantial contributors to the depletion of the ozone layer[11].

Against this bleak background, the most obvious benefit of the Green Revolution is dwindling in effectiveness. Studies indicate that crop yields are no longer increasing at the rate required to keep pace with population growth and that the ideal of doubling production by 2050 could be wildly optimistic[12].

Relatedly, sequestering organic carbon in soil is now accepted as a potent weapon in the fight against climate change. Yet many of the methods that proliferate today are not only inherently carbon-intensive: they are eroding, degrading and destroying soils, rendering them ever less fit for producing food and prompting the UN Convention to Combat Desertification (UNCCD) to condemn intensive agriculture as “an extractive industry”[13].

According to research published in Nature in 2018, the negative environmental impacts of food production could soon exceed “the planetary boundaries that define a safe operating space for humanity”[14]. To avoid this fate, said the authors, “technological changes and dedicated mitigation measures” should be seen as essential. It is a familiar story: we have innovated our way into trouble, and now we need to innovate our way out of it again.

Dangerously outmoded agricultural approaches take insufficient account of the damage they are wreaking and the pervasiveness of its repercussions.

Agriculture and the fight against climate change

A 2020 study by McKinsey & Company suggested the 15 most effective measures the agricultural industry could take to help address the threat of climate change. These are shown below, presented in descending order of potential impact[15].

Whether directly or indirectly, agtech has a part to play in ensuring the effectiveness of each of these measures. Citing the role of "next-horizon technologies", the research's authors said: "Agriculture... now has an opportunity to make yet another major contribution to humanity's success during this crucial window for action."

Farming's top 15 measures for tackling climate change

1. Adopt zero-emissions on-farm machinery and equipment
2. Employ GHG-focused genetic selection and breeding
3. Improve fertilization practices in rice cultivation
4. Improve animal health monitoring and illness prevention
5. Optimize the animal feed mix
6. Expand use of animal feed additives
7. Improve rice paddy water management
8. Expand use of anaerobic manure digestion
9. Expand use of feed-grain processing for improved digestibility
10. Expand adoption of direct seeding in rice cultivation
11. Expand uptake of technologies that increase livestock production efficiencies
12. Apply nitrification inhibitors on pasture
13. Scale low-tillage and no-tillage practices
14. Reduce nitrogen overapplication in China and India
15. Expand adoption of controlled-release and stabilized fertilizers

Source: McKinsey & Company: Agriculture and Climate Change: Reducing Emissions Through Improved Farming Practices, 2020

3.3. Advances and enhancement

Writing for the World Economic Forum (WEF) in 2019, Karn Manhas, founder and CEO of Canadian agtech company Terramera, lamented farming's "yawning tech gap". "In our approaches to land management, resource use, labor, transportation and more, we're firmly stuck in an outdated industrial model," he said. "Our current methods got us to where we are, but the way we farm now isn't sustainable for the planet, for individuals or for societies."[16]

The long-term answer, said Manhas, would lie in innovation and disruption. Malthus apparently overlooked the power of these twin forces when he predicted "premature death in some shape or other... for the human race" in An Essay on the Principle of Population; so did American biologist Paul Ehrlich when he re-raised the specter of resource scarcity, starvation and societal collapse in his highly influential 1968 book, The Population Bomb[17].

It is by no means inevitable that innovation and disruption will improve our lives, especially if they are overtly technology-driven. They occasionally unleash forces so awesome that we can hardly comprehend or control them. They can lead to outcomes that bear scant resemblance to those originally envisaged. They sometimes prove disappointingly ephemeral. Not least today, they are often the stuff of cozy convenience or mere entertainment.

Yet we believe that these shortcomings do not apply to agtech. This is not what former Facebook executive Chamath Palihapitiya has denounced as "intellectual sterilization"[18]. It is not a cynical treadmill of enforced obsolescence. It is not a dubious question of offsetting one form of overconsumption by concocting another.

As Manhas stressed in his WEF piece, this is an attempt to safeguard collective survival. It is an act of absolute necessity – both for developed countries and for those caught in a poverty-fueled spiral of environmental and economic decline. It is a case of trying to do more with less. As citizens and as investors, we need to acknowledge it is an instance of technological progress whose life-enhancing capacity is manifest.

We also need to acknowledge it as a reflection of momentous shifts in consumer tastes. Vegetarianism, veganism, heightened awareness of the relationship between nutrition and health, concerns over animal welfare – these and other factors are putting ever more pressure on industrialized farming while at the same time augmenting agtech's relevance and appeal.

COVID-19 has only accelerated this concomitant fall and rise. In the words of Erez Galonza, CEO of Infarm, the pandemic has "exposed the cracks" in conventional policies and practices. The need for a new model – one that is legitimately sustainable and explicitly geared toward making lives not only easier but better – has never been so patent.

As citizens and as investors, we need to acknowledge this as an instance of technological progress whose life-enhancing capacity is manifest."

The organic food boom

Ecovia Intelligence, a research and consulting firm specializing in ethical product industries, reported in April 2020 that retailers worldwide were experiencing "hefty sales increases" for organic products during the COVID-19 pandemic. Analogous spikes have been witnessed during similar events in the past – for example, the mid-1990s BSE crisis in the UK and the 2004 SARS outbreak in Asia – with demand remaining strong thereafter.

Ecovia has posited that the market for organic food could now grow massively during the next half-decade. "With COVID-19 changing the way we shop and eat," said the research's authors, "the next leap – to $150 billion – could be within the next five years." Again, agtech would be critical to this trajectory.

Growth of the organic food market in $50 billion increments: timescale and overall value

Early 1990s to 2008	2008 to 2018	2018 to 2025
$50 billion	$100 billion	$150 billion?

Source: Ecovia Intelligence: The Global Market for Organic Food and Drink: Trends and Future Outlook, 2020

4

Growth

4.1. From outmoded to emergent

We have discussed how agtech has emerged in response to the threat of resource scarcity, climate change and other global challenges that have defined the early decades of the 21st century. In tandem, it has also emerged in response to new consumer preferences – and, of course, the advent of new technologies.

We have also touched on how agriculture has sought to help humanity innovate its way out of trouble in the past. Agtech is now essentially underpinning what would constitute a fourth agricultural revolution: the first occurred with the birth of farming around 12,000 years ago, the second came with the reorganization of farmland following the end of feudalism in Europe, and the third – as we have seen – gave us the Green Revolution.

We have proposed that the Green Revolution appears to have run its course and that an Ever-Green Revolution – that is, one likely to prove sustainable in every sense – is now needed. We have also observed that agtech's ability to deliver such a revolution should demonstrate technology's frequently untapped and overlooked capacity to truly improve lives on an enormous scale.

So how quickly is this revolution now unfolding? In 2010, according to the Produce Marketing Association, agtech attracted less than $100 million in investment[19]. In 2016, in a report highlighting "huge market potential", Deloitte suggested that agriculture was "on the verge of turning into a high-tech industry"[20]. In 2020, amid the ravages of the COVID-19 pandemic, AppHarvest alone raised $475 million when it listed on the Nasdaq[21].

Various sub-sectors – and even sub-sub-sectors – are now well established. For instance, AgFunder identifies farmtech as a branch of agtech and specifies within it further areas of specialization such as agbiotechnology, agribusiness marketplaces, bioenergy and biomaterials, midstream technologies, farm-to-consumer e-grocery and robotics, mechanization and equipment[22].

A simpler framing may be to divide agtech into three broad categories. The first employs current technologies to augment existing methods – for example, using sensors and AI to monitor plants. The second employs current technologies to develop novel methods – for example, vertical farming. The third focuses on developing new technologies that will lead in turn to further radical disruption – for example, lab-grown meat products.

Much of this activity so far has gone relatively unnoticed – both by the wider population and by the investment community. Many people are still unaware that what was once cultivated only in fields is now routinely cultivated inside giant indoor farms or multi-story buildings; that the apples they buy in supermarkets may have been gathered by autonomous flying fruit-pickers; and that cattle farmers can now even take advantage of facial-recognition software for their cows. Even if it is not occurring in plain sight, though, the revolution is under way – and it presents myriad opportunities.

A growth sector

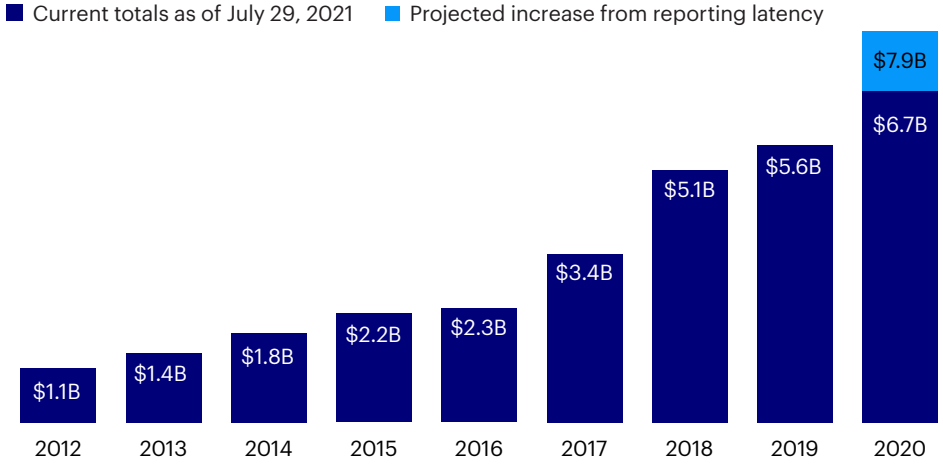
Farmtech can be defined as the agtech sub-sector covering areas including crop inputs, machinery, devices, software, analytics and logistics. Agtech venture capital specialist AgFunder has calculated that investment in this space increased by 41% year-on-year in 2020.

As shown in the chart below, farmtech investment has risen significantly throughout the past half-decade. AgFunder has predicted that ever-greater consumer and regulatory pressure, including the incorporation of ESG considerations, will continue to support the trend toward "realigning products and practices for long-term sustainability".

“

In 2010 the sector attracted less than $100 million in investment. In 2020 AppHarvest alone raised $475 million when it listed on the Nasdaq.

Investment in the farmtech sub-sector, 2012-2020



Source: AgFunder: AgFunder Farm-Tech Investment Report 2021, 2021

4.2. Expansion and opportunity

As remarked earlier, the Green Revolution began in Mexico in the late 1940s. It first spread to the US, which went from a net importer to a net exporter of wheat in barely 20 years; then to countries such as India, Pakistan and Bangladesh, allowing them to avoid famine; and eventually to South-East Asia, Africa and the Middle East, all of which were able to double or even treble yields. Its influence – both positive and negative – is still felt globally today.

For all intents and purposes, the cradle of the present revolution lies in the US. According to AgFunder, 83% of all investment in farmtech in 2020 was centered on America, with 35% of the total going to California[23]. Yet there is ample reason to expect that this revolution, like its predecessor, will have worldwide reach – and soon.

The biggest non-US deal in the farmtech sub-sector in 2020 involved Chinese drone company XAG, which attracted $182 million in funding[24]. Sustainable protein provider Ÿnsect, which was set up by scientists and environmental activists in 2011, accounted for $139 million of the $472 million invested in French farmtech businesses[25].

In the UK, meanwhile, online and High Street retailers alike are integrating solutions such as vertical farming into their offerings. Marks & Spencer has introduced localized vertical farms in some of its stores[26], while Ocado has made a multi-million-pound commitment to satisfying “fundamental consumer concerns on freshness and sustainability”[27].

The success of agtech is also likely to be crucial to those who still live on the formal economy’s fringes, where the perils of resource scarcity are writ large. Professor Jaideep Prabhu, of the University of Cambridge, is among the scholars who have drawn attention to the role of “frugal innovation” in guaranteeing food security for billions of individuals[28].

The environmental dimension further underscores agtech’s likely importance over the long term, with low-carbon technologies in particular set to be key. AgFunder has reported “an unprecedented amount of discussion about soil carbon within farmtech and farming circles, [with] no sign of that abating”[29]. Such efforts have been described as “indispensable for the adaptation of agricultural systems”[30].

It has been claimed that the potential of the agtech market is “nearly limitless, precisely because our appetites are, too”[31]. We might surmise that it is also nearly limitless because agtech seeks to address issues that affect the whole planet. To view such matters in terms of opportunity is not to trivialize them: rather, it is to accept that in this arena, as in so many others, responsible investing can bring about urgently needed change.

“

There is ample reason to expect that this revolution, like its predecessor, will have worldwide reach – and soon.

Toward a global phenomenon

The US is the principal hotbed of agtech. As such, it continues to attract the overwhelming majority of investment in this sector. Yet the market is growing in many parts of the world.

According to AgFunder, nine countries each attracted more than $100 million in farmtech investment alone in 2020. By comparison, global investment in agtech as a whole amounted to less than $100 million just a decade earlier.

Top 15 countries for farmtech investment in 2020

1. US: $4 billion
2. France: $472 million
3. China: $341 million
4. India: $290 million
5. Canada: $240 million
6. Israel: $227 million
7. Germany: $175 million
8. UK: $163 million
9. Netherlands: $105 million
10. Finland: $89 million
11. Brazil: $67 million
12. Japan: $60 million
13. Russia: $59 million
14. Sweden: $58 million
15. Australia: $57 million

Source: AgFunder: AgFunder Farm-Tech Investment Report 2021, 2021

4.3. Agtech in action: AppHarvest

AppHarvest operates some of the world’s largest high-tech indoor farms. These facilities are designed to grow non-GMO, chemical-pesticide-free produce while using up to 90% less water than traditional outdoor farming methods.

Entrepreneur Jonathan Webb founded the company in 2017 after working in the solar industry. Having learnt about the use of state-of-the-art greenhouses to grow fruit and vegetables in the Netherlands, he returned to his native Kentucky to launch a US business with a similarly cutting-edge approach to “controlled environment” agriculture. AppHarvest’s first greenhouse, covering 60 acres, was built after he secured an $82 million deal with a sustainability-focused venture capital firm in 2019.

AppHarvest has three overarching objectives, the first of which is to drive positive environmental change in agriculture. It aims to do this through numerous means, including limiting its carbon footprint and energy use, optimizing efficiency and yields, maximizing recycling and utilizing advances such as nanobubble technology, computer vision, machine learning and hybrid lighting.

Its second objective is to empower employees in Appalachia, a region where coal-mining was once the main source of employment. The rapid collapse of the coal industry in the face of renewable energy’s rise left local people in dire need of a more resilient economy – one that AppHarvest is now providing. Webb has stated that Appalachia “desperately needs investment from responsible companies, creating jobs that prioritize the worker”[32].

AppHarvest is now one of the first publicly traded PBCs, having listed on the Nasdaq via a SPAC just weeks after shipping its inaugural harvest.

Relatedly, AppHarvest's third objective is to improve the communities in which it is based. So far this has included setting up education programs, forming partnerships and encouraging healthier diets, as well as targeting capital investment of around $1 billion by 2025.

AppHarvest began as a public benefit corporation (PBC) and then became certified as a B Corp – in effect, a business that balances purpose and profit. It is now one of the first publicly traded PBCs, having listed on the Nasdaq via a SPAC just weeks after shipping its inaugural harvest. In July 2021 Forbes credited the company with "kicking off a SPAC trend" within agtech, especially in the farmtech sub-sector[33].

Writing in Feed the Future, AppHarvest's 2020 annual PBC report, Webb said: "We believe in good and are inspired daily by the faith and grit of those who have chosen to share their talents with us and join our mission. This small group refuses to back down from challenges... Our goal is to build a more resilient food system."[34]

How AppHarvest leverages tech

Indoor farms such as those operated by AppHarvest encapsulate the challenge of doing more with less. In other words, they aim to cultivate more produce by using fewer resources. As AppHarvest says: "Why use 1,800 acres to grow what you can on 60 acres?"

Of course, this would not be possible without state-of-the-art technology. Below are some of the "tools" that AppHarvest uses in attempting to produce per-acre yields 30 times higher than those delivered by conventional farming.

Nanobubble technology
AppHarvest increases nutrient absorption by supplementing recycled rainwater with oxygen. This reduces the temperature of plants' root zones and boosts yields.

Computer vision
High-resolution cameras attached to roaming robots map every square foot of AppHarvest's facilities, providing real-time alerts about risks related to pests and diseases.

Artificial intelligence and machine learning
Drawing on a wealth of data gathered from hundreds of sensors, AppHarvest is able to precisely fine-tune environmental and nutritional conditions for plants in real time.

Hybrid lighting
By using a combination of LED and high-pressure sodium lighting rather than only the latter, AppHarvest can apply higher levels of light while using significantly less energy.

Climate screening
AppHarvest uses a high-tech energy screen that can accurately control an indoor environment. This helps cut heating costs, as well as extending harvesting days.

Source: AppHarvest: Feed the Future: Annual Public Benefit Corporation Report, Fiscal Year 2020, 2021

5

Q&As

5.1. Maria Lettini, FAIRR: beyond industrialization

Maria Lettini is Executive Director of FAIRR (Farm Animal Investment Risk and Return), a global investor network that raises awareness of the ESG risks associated with intensive food production. She was previously Head of the Americas for the Principles for Responsible Investment (PRI), leading its signatory relations and outreach strategy.

In this Q&A Maria reflects on how decades of failings have produced an unsustainable status quo in agriculture. She also explains why agtech is likely to be central to the quest to completely transform the industry and place it on a path genuinely fit for the long term.

Why is farming as we know it today no longer sustainable?

It's kind of a long story, but it's also a story we really need to understand if we want to avoid an unhappy ending. So let's try to keep it reasonably short and simple.

We can look throughout history and find numerous occasions when humanity realized existing means of food production weren't up to the job anymore. The most significant of these occasions in relatively recent history came after the Second World War, when many countries faced the challenge of achieving self-sufficiency.

The Green Revolution met this challenge, and for two or three decades it seemed to provide all the answers. But concerns about its unintended consequences surfaced as early as the 1980s, and we now know it wasn't the "silver bullet" solution it originally appeared to be.

With the benefit of hindsight, we also now appreciate the Green Revolution coincided with and even contributed to the industrialization of agriculture. Production roughly trebled between 1960 and 2015, during which period factory farming – or intensive farming, as it's also known – established itself as the sector's dominant paradigm.

So today we have not just the unintended consequences of the Green Revolution, including huge use of water and of fertilizers, but also the longstanding prevalence of the industrialized model. And these issues have become central to many of the biggest threats confronting the planet, including climate change, environmental devastation, biodiversity loss and the emergence and spread of highly resistant pathogens.

That means we're now in many ways back where we were when the Green Revolution began, in so far as we're realizing yet again that our existing means of food production aren't fit for purpose. It's time to move on.

Does this mean completely abandoning the industrialized model?

It certainly means abandoning a lot of the policies and practices that have come to define it. For example, if we're talking about the legacy of the Green Revolution – or even if we're talking about hopes of ushering in an Ever - Green Revolution – which aspects of factory farming today can we truly describe as "green"?

We need an agricultural model that meets the challenges of hunger and resource scarcity while remaining sympathetic to the environment, cognizant of animal welfare, conducive to human health and geared toward long-term survival. In short: we need a model that safeguards the future instead of threatening it.

Any revolution has to be rooted in new thinking, and agtech is the main source of innovation in this space.

So do we need to totally reinvent agriculture?

When an industry or a sector gets to a point where its policies and practices are obviously no longer sustainable, ideally, it should commit to a reinvention of some sort – preferably one with a clearly long-term outlook. Instead, unfortunately, what often happens is that it sticks to a "business as usual" approach and stays focused on the short term – regardless of how damaging that might be.

This is what we've witnessed in agriculture. Remember that doubts about the sustainability of the Green Revolution and factory farming have been voiced for something like 40 years. Potential tipping points have come and gone. Warnings have been ignored. The same damaging path has been followed.

The good news is that we're now seeing more and more evidence of positive change – not just from new market entrants but from established companies that are willing to embrace disruption. There are growing signs that the Ever-Green Revolution is genuinely under way.

Where does agtech fit into this picture?

It's a cornerstone of the necessary transformation. Any revolution has to be rooted in new thinking, and agtech is the main source of innovation in this space.

There are businesses out there that are evolving, and that's great – they're playing a part as well. But the future ultimately lies in comprehensive transformation, which is where agtech is leading the way.

Technology – especially digitization – is driving positive change in almost every walk of life, so why should agriculture miss out? We can't keep using piecemeal innovation to preserve an unsustainable status quo, so let's use radical innovation to leave the worst of the industrial era behind and begin building something that's both different and better.

Is it possible that an agtech-driven revolution could meet the same fate as the Green Revolution, which began with the best intentions but seemed to lose its way over time?

I think agriculture during the latter half of the 20th century suffered from two enduring failings that were closely related to each other. The first was that suboptimal policies and practices became normalized. The second was that innovation was in the main used to prop up existing systems rather than to create new ones.

Those traps are always going to be there. We may even reach a point sometime in the future when we need another rethink. But the best way to avoid that is to keep looking ahead and keep innovating.

5.2. Glen Yelton, Conor Hartnett and Dr Henning Stein, Invesco: life-enhancing tech

Glen Yelton is Invesco's Head of ESG Client Strategies in North America. He was previously a Director of ESG and Impact Investing at OppenheimerFunds and also held ESG-related and research-related roles at a number of investment, data and ratings businesses.

Conor Hartnett is Invesco's ESG Client Strategies Manager in EMEA. He previously worked for CDP (formerly the Carbon Disclosure Project), including serving as its Senior Project Officer for Capital Markets.

Dr Henning Stein is Invesco's Global Head of Thought Leadership. He and his team provide insights and perspectives to the institutional investor and financial adviser communities worldwide.

In this Q&A Glen, Conor and Henning discuss the broader notion of whether investments in technology can be regarded as aligned with ESG principles. Presenting agtech as a classic example of genuinely life-enhancing tech, they outline the key distinction between ephemeral augmentation and long-term necessity.

In the age of ESG, when impact beyond the bottom line is a crucial consideration, is it difficult to convince some investors that tech can really make our lives better?

HS: Although it sounds like a question for philosophers, this is a tremendously important question for investors. Few people would doubt technology makes our lives easier, but whether it makes our lives better is a more complex matter.

Some investors think of technology only in terms of Big Tech – Amazon, Apple, Facebook, Microsoft and so on. Tech titans such as these have clearly transformed our lives, and it seems reasonable to suggest the overall impact has been to render day-to-day tasks more efficient and less onerous.

The attractions of Big Tech from an investment perspective are obvious as well. Notwithstanding blips and bubbles, anyone who has backed these businesses over the longer term is likely to have earned healthy returns.

But whether Big Tech actually makes our lives better is a moot point. For example, does a new algorithm for iTunes make our lives better in the strictest sense? Wouldn't our lives really be better if Big Tech were to channel its brilliance into tackling the enormous challenges and existential threats we all face?

None of this is intended to pass judgement on Big Tech or its preferred areas of research and development. The point is simply that the life-enhancing capacity of much of the disruptive technology that defines our age is increasingly – and perhaps rightly – disputed.

So is the key difference when we think about agtech that this is a question of necessity?

GY: That's exactly what it is. We just have to consider what's at stake here. Climate change will put our food systems under enormous strain, and many food commodities – such as cattle, palm oil and soy – are at the same time contributing to this change through destructive processes such as deforestation and emissions.

Water scarcity will likely be the first large-scale, life-threatening impact we see from climate change, and agriculture is also the largest industrial consumer of fresh water. In addition, it's estimated 50% of global GDP is derived from nature, yet our agricultural practices are one of the largest drivers of biodiversity loss.

Bearing all this in mind, it's extremely difficult to question the life-enhancing capacity of any novel technology that helps save us from ourselves. If an innovation is mindful of the future of our planet and its inhabitants, as agtech is, then it must make our lives better.

Investment is frequently described as a matter of finding opportunity in risk. Does finding opportunity in the quest to feed the world trivialize a tremendously important challenge?

HS: No, because the best ideas need to be supported by capital if they're to fulfil their potential. The alternative is that they're left incapable of achieving their aims, as a consequence of which everyone might lose out.

It should be stressed that it's wrong to infer the investment community is unique in its ability to safeguard the future, serve the greater good, counter existential threats and so on. It's true that many of these goals can't be achieved without investors, but it's also true that investors can't achieve them without the participation of others – policymakers foremost among them.

Historically, many of the ESG commitments championed by those in policy circles have been inadequately defined in their demands and unduly modest in their aims. Few could be described as genuinely radical from an innovation perspective. By and large, they can be classified as incremental and expedient. Investment shouldn't be thought of as a perpetual remedy for these shortcomings, because this invites a placebo effect.

That all said, the major threats confronting humanity need to be viewed through the prism of ESG. Crucially, so does tech.

There are many tech investments aligned with the underlying objective of delivering financial performance while benefiting as many stakeholders as possible. This is a useful rule of thumb if our concern is whether technological progress really does improve our lives, and it's obvious that agtech fits this bill.

It's extremely difficult to question the life-enhancing capacity of any novel technology that helps save us from ourselves.

Cynics might point out that our lives aren't going to be enhanced overnight. What about businesses – and even investors – that won't look beyond short-term gain?

CH: It's well known that humans are prone to prioritizing the short term over the long term. We often fall into the "tragedy of the commons" trap as well. But in the end we're also hardwired for cooperation and reciprocity.

We may be able to get away with working in our own best interests at the cost of everyone else's, particularly in large communities, but it's usually a risky strategy that will eventually catch up with us. Although competition and profit lead to greater prosperity, we have to recognize the value and interconnectivity of all stakeholders in order to be truly sustainable and ensure long-term prosperity.

Our food system exemplifies the balances that need to be struck. It's something we're all so close to yet at the same time far removed from. It's a system in which we're more than ready to prioritize cost and convenience over long-term health and security, yet it's also a system that's vital to our survival.

Even in the new age of stakeholder capitalism, there's little doubt that we can expect huge impediments to hopes of achieving a genuinely stable and prosperous society. But if we recognize there are ways to improve all our lives -– and if we recognize agtech is one of them – we'll be moving in the right direction.

5.2. Jonathan Webb, AppHarvest: farmers and futurists

Jonathan Webb is the founder and CEO of AppHarvest. Having previously worked on a major solar project with the US Department of Defense, he established the company in 2017 with the goal of transforming Appalachia – a region devastated by the end of coal-mining – into America's agtech capital.

In this Q&A Jonathan explains why agriculture is at an inflection point and why his company favors a long-term view. He also discusses his approach to ESG and why he believes sustainability and profitability to be perfect bedfellows.

AppHarvest is building some of the world's largest controlled environment agriculture (CEA) facilities, which you describe as "the third wave of sustainable infrastructure". What do you mean by that?

The first wave came 20 years ago, with renewable energy. The second wave came 10 years ago, when Tesla made electric vehicles popular in the mainstream. And now the third wave is CEA – using technology to produce a lot more food with fewer resources.

The last great technological revolution in American farming that most folks can think of was when the tractor was introduced. Now it's artificial intelligence and robotics and using data to make decisions – which is why I refer to our employees as farmers and futurists.

At our flagship indoor farm in Morehead, Kentucky, we're farmers – we grow tomatoes by using sunlight and rainwater. But we're also futurists, because we combine a technology team with a great plant science group and pull technology in to drive nature from behind.

Mexico was the cradle of the original Green Revolution. Would it be fair to say that it now embodies much of what is wrong with agriculture today?

As the country where the US has moved most of its fruit and vegetable production, Mexico really underlines why our industry is at an inflection point. It shows why you have to care about where a product originates if you're a food service outlet or grocery store today.

One aspect is transportation concerns. These products are being imported and shipped thousands of miles. A tomato from Mexico going to the East Coast of the US can sit on a truck for two or three weeks.

There are also labor concerns. We're feeding our country through the work of people in Mexico who aren't making a living wage. US Customs and Border Protection blocked some tomato imports in October 2021 because an investigation found evidence of deception, withholding of wages, debt bondage and other abusive working and living conditions – and I worry that this is just the tip of the iceberg.

Farms in Mexico are also using chemical pesticides that are illegal in many other countries, which the US Environmental Protection Agency has difficulty tracking. It's nearly impossible to have full transparency.

Finally, let's not forget the weather. Think how many times leafy greens have been pulled from the shelves in the past few years. We like to say our goal is to disrupt agriculture, but the reality is that climate beat us to it. We have to protect against extreme weather events – whether that's drought or flooding or wind shear or wildfires – that affect yield and product availability.

And do you feel CEA addresses all these issues?

Yes, and I also believe where we're doing what we do is as important as why we're doing it. We picked Kentucky as our location for several reasons.

First, it happens to be an area that's very well suited for this industry. It has had one of the wettest decades on state record, and it continues to get wetter – which is important, because 95% of the fruits or vegetables we're growing is water. We're collecting rainwater and avoiding harsh chemical pesticides.

Our central location also means we can reach nearly 70% of the US population within a day's drive. This stands to cut food waste tremendously. We can reduce food miles and time to market significantly. It's good for the planet, and it's ultimately good for the consumer.

Kentucky was once one of the largest coal-producing states, providing energy to much of the US. Now we want it to be known for another type of energy production – agtech and sustainably grown food that powers the human body.

Many of the coal mines in Central Appalachia have shut down, so we're putting our facilities here to create living-wage jobs in communities that most need them. Our employees have full healthcare and equity in the company. Also, through an extensive agtech educational program in high schools, we're growing the next generation of farmers and futurists.

Are you convinced that the end of farming as we know it is imminent?

I live in coal country. Almost every company in the coal industry has gone bankrupt over the past 10 years – that's how quickly an industry can shift.

The next generation gets it. Sustainability matters to them, because the issues of today are going to impact them the most in the future. A recent study I read interviewed 10,000 young people in 10 different countries, and 56% of them said they're deeply concerned about the future based on the climate disruption that continues to unfold in front of us.

So food supply instability isn't just a US problem – it's global. The whole world is changing. Regulators and consumers are pushing back, and people are becoming more aware of where the products they use are made or grown.

We're cognizant that there's going to be plenty of large players working to solve our food and agriculture problems, and we plan to be one of them.

There are great ways to farm outdoors, but the problem is that we've destroyed our planet to the point where it's almost impossible to predict yields and to feed up to nine billion people 10, 20 or 30 years from now by using traditional methods. Many conventional forms of agriculture should really be categorized as extractive industries – they're extracting nutrients out of the ground at such a rate that they're not being replenished.

So we urgently need to figure out how we can build systems to maintain the current level of supply while extracting. It's not us versus soil – it's a question of figuring out how to complement the farmers who are doing it right.

AppHarvest has achieved significant success in a relatively short time. Does this influence how you look ahead?

The world's food and agriculture problems aren't going to be solved overnight or in a month, a quarter or even a year. We see this as a 30-year journey. We're at the very beginning of our first decade, and we're looking at how we're going to judge the company in decade one, decade two and decade three.

We want to build an organization that's going to be able to go toe-to-toe with the larger incumbents globally, and the best way to do that is to have the rigor of being a publicly traded company. To bring transparency and trust to agriculture, we welcomed the additional scrutiny this entails.

We're working to set a new standard for sustainable, ethical agriculture. But AppHarvest isn't going to save agriculture or build a stable, climate-resilient food supply on its own.

Much like one energy company won't be powering the world, there isn't going to be one food company feeding the world. Whatever we can do to be a team player, we're raising our hand and saying: "We want to collaborate." To me, anyone who's growing good, clean produce and avoiding harsh chemical pesticides is a colleague rather than a competitor. We're cognizant that there's going to be plenty of large players working to solve our food and agriculture problems, and we plan to be one of them.

Do you feel that investors tend to back a business like yours to make money or to make a difference – or both?

ESG principles should be at the core of profitability and the foundation for building a resilient, future-proof company. We're past the point where investors invest because it makes them feel good – a business has to work.

There's a lot of issues in agriculture right now, and we have much to do. But we firmly believe we can use ESG metrics to clean up our food supply and create better food systems.

We also think being true to our ESG values is a competitive advantage that's going to make us more successful in the years to come. Sustainability is profitability – that's how ESG is going to attract the financing needed to rebuild our world.

6

Conclusion

Agtech is about building a better future. It is about encouraging sustainability and eradicating antiquated, damaging models whose relevance is rapidly nearing its end.

The recorded history of agriculture is punctuated with milestone breakthroughs, many of which have transformed farming. Long before Norman Borlaug, the principal architect of the Green Revolution, there was Jethro Tull and the horse-drawn seed drill; Eli Whitney and the cotton gin; John Deere and the steel plough; Hiram Moore and the combine harvester; and many more.

However primitive they might appear now, each of these inventions represented the cutting edge of technology at the time. The cutting edge today is very different, but the underlying goal is much the same: to increase productivity as effectively and as efficiently as possible.

Agtech is at the forefront of efforts to realize this objective. In the grandest tradition of innovation, it is striving to meet unmet needs. A powerful reflection of the rise of ESG, it is quickly emerging as an arena capable of delivering growth in every sense of the word.

As we have seen, the numbers speak for themselves. It is worth repeating that, while the sector as a whole attracted less than $100 million in investment in 2010, a single agtech company – AppHarvest – raised $475 million when it listed on the Nasdaq in 2020.

Ultimately, as AppHarvest itself has stressed, agtech is about building a better future. It is about encouraging sustainability and eradicating antiquated, damaging models whose relevance is rapidly nearing its end. To quote Jonathan Webb: "The industry is at an inflection point. If you look at the food system today... these companies are like the cigarette companies 40 years ago."[35]

Even in the eyes of Borlaug – let alone Tull, Whitney, Deere and Moore – agtech would be the stuff of science-fiction. Yet science-fiction has tended to offer only dystopian visions of societies hopelessly blighted by overpopulation and resource scarcity[36].

By contrast, science-fact is now providing real-world solutions. Agtech is already enabling and underpinning a hugely significant shift in our relationship with food in particular and the world around us in general. Not for the first time, the sphere of agriculture is finding a way to respond to humanity's most pressing challenges.

7

References and suggested further reading

AgFunder: *AgFunder Farm-Tech Investment Report 2021*, 2021

Amelung, W, Bossio, D, de Vries, W, Kögel-Knabner, I, Lehmann, J, Amundson, R, Bol, R, Collins, C, Lal, R, Leifeld, J, Minasny, B, Pan, G, Paustian, K, Cumpel, C, Sanderman, J, van Groenigen, J, Mooney, S, van Wesemael, B, Wander, M, and Chabbi, *A: Towards a Global-Scale Soil Climate Mitigation Strategy*, 2020

AppHarvest: *Feed the Future: Annual Public Benefit Corporation Report, Fiscal Year 2020,* 2021

Daily Mail: "Farming goes vertical", 4 August 2020

Das, A: *Industrial Revolution 4.0: Ghosts of Disruption Past, Present and Future,* 2018

Deloitte: *From Agriculture to Agtech: An Industry Transformed Beyond Molecules and Chemicals,* 2016

Ecovia Intelligence: *The Global Market for Organic Food and Drink: Trends and Future Outlook,* 2020

Food and Agriculture Organization: T*ackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities,* 2013

Food and Agriculture Organization: *The Future of Food and Agriculture: Trends and Challenges,* 2017

Forbes: "Farmtech investing is accelerating faster than foodtech and general VC – new report", 29 July 2021

Global Hunger Index: *2020 Global Hunger Index,* 2020

Guardian: "Third of Earth's soil is acutely degraded due to agriculture", 12 September 2017

Harrison, H: *Make Room! Make Room!,* 1966

Klümper, W, and Qaim, M: *A Meta-Analysis of the Impacts of Genetically Modified Crops,* 2014

Lombardo, M, Stein, H, and Lettini, M: *Appetite for Change: Food, ESG and the Nexus of Nature – Part I: Lessons from the COVID Crisis*, 2020

Malthus, T: *An Essay on the Principle of Population*, 1798

McKinsey & Company: *Agriculture and Climate Change: Reducing Emissions Through Improved Farming Practices,* 2020

Motley Fool: "An interview with AppHarvest founder and CEO Jonathan Webb", 4 June 2021

Ocado Group: "Ocado brings its innovation and automation expertise to sustainable vertical farming", 10 June 2019

Prabhu, J: *Frugal Innovation: How to Do More With Less,* 2015

Produce Marketing Association: "Agtech investing: where is the smart money going?", 25 February 2021

Ray, D, Mueller, N, West, P, and Foley, J: *Yield Trends Are Insufficient to Double Global Crop Production by 2050,* 2013

Social Capital: "2019 Annual Letter", 2019

Springmann, M, Clark, M, Mason-D'Croz, D, Wiebe, K, Bodirsky, B, Lassaletta, L, de Vries, W, Vermeulen, S, Herrero, M, Carlson, K, Jonell, M, Troell, M, DeClerck, F, Gordon, L, Zurayk, R, Scarborough, P, Rayner, M, Loken, B, Fanzo, J, Godfray, H, Tilman, D, Rockström, J, and Willett, W: *Options for Keeping the Food System Within Environmental Limits,* 2018

United Nations: "World population projected to reach 9.8 billion by 2050 and 11.2 billion in 2100", 21 June 2017

United Nations: *World Population Prospects 2019*, 2019

World Economic Forum: "Why the agtech boom isn't your typical disruption", 25 February 2019

Yelton, G, Stein, H, Hartnett, C, and Lettini, M: *Appetite for Change: Food, ESG and the Nexus of Nature – Part II: The search for sustainability,*, 2021

1. See Lombardo, M, Stein, H, and Lettini, M: Appetite for Change: Food, ESG and the Nexus of Nature – Part I: Lessons from the COVID Crisis, 2020.
2. See Yelton, G, Stein, H, Hartnett, C, and Lettini, M: Appetite for Change: Food, ESG and the Nexus of Nature – Part II: search for sustainability, 2021.
3. See AgFunder: AgFunder Farm-Tech Investment Report 2021, 2021.
4. Malthus warned: "The power of population is so superior to the power of the earth to produce subsistence for man that premature death must in some shape or other visit the human race." See Malthus, T: An Essay on the Principle of Population, 1798.
5. See, for example, Klümper, W, and Qaim, M: A Meta-Analysis of the Impacts of Genetically Modified Crops, 2014.
6. See, for example, Food and Agriculture Organization: The Future of Food and Agriculture: Trends and Challenges, 2017.
7. See Global Hunger Index: 2020 Global Hunger Index, 2020.
8. Ibid.
9. See, for example, United Nations: "World population projected to reach 9.8 billion by 2050 and 11.2 billion in 2100", 21 June 2017.
10. See, for example, Food and Agriculture Organization: Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities, 2013.
11. See, for example, McKinsey & Company: Agriculture and Climate Change: Reducing Emissions Through Improved Farming Practices, 2020.
12. See, for example, Ray, D, Mueller, N, West, P, and Foley, J: Yield Trends Are Insufficient to Double Global Crop Production by 2050, 2013.
13. See, for example, Guardian: "Third of Earth's soil is acutely degraded due to agriculture", 12 September 2017.
14. See Springmann, M, Clark, M, Mason-D'Croz, D, Wiebe, K, Bodirsky, B, Lassaletta, L, de Vries, W, Vermeulen, S, Herrero, M, Carlson, K, Jonell, M, Troell, M, DeClerck, F, Gordon, L, Zurayk, R, Scarborough, P, Rayner, M, Loken, B, Fanzo, J, Godfray, H, Tilman, D, Rockström, J, and Willett, W: Options for Keeping the Food System Within Environmental Limits, 2018.
15. McKinsey's suggestions relate strictly to farming practices rather than to innovations within the broader food system – hence the absence in this instance of important shifts such as a greater focus on plant-based products.
16. See World Economic Forum: "Why the agtech boom isn't your typical disruption", 25 February 2019.
17. Ehrlich did much to rekindle popular and policymaker interest in the problem of resource scarcity, but his arguments were famously undermined when he lost a high-profile wager with pro-innovation economist Julian Simon. See, for example, Das, A: Industrial Revolution 4.0: Ghosts of Disruption Past, Present and Future, 2018.
18. Palihapitiya founded venture capital firm Social Capital after leaving Facebook. He has accused companies such as Apple, Amazon and Google of wasting intellectual capital on "irrelevant" projects, becoming "more focused on protecting their monopolies than advancing humanity" and reneging on promises "to change the world and eradicate its evils". See, for example, Social Capital: "2019 Annual Letter", 2019.
19. See, for example, Produce Marketing Association: "Agtech investing: where is the smart money going?", 25 February 2021.
20. See Deloitte: From Agriculture to Agtech: An Industry Transformed Beyond Molecules and Chemicals, 2016.
21. See, for example, Forbes: "Farmtech investing is accelerating faster than foodtech and general VC – new report", 29 July 2021.
22. See, for example, AgFunder: AgFunder Farm-Tech Investment Report 2021, 2021.
23. Ibid.
24. Ibid.
25. Ibid.
26. See, for example, Daily Mail: "Farming goes vertical", 4 August 2020.
27. Ocado CEO Tim Steiner has expressed his hope that it could soon be possible for purchases to be "delivered to a customer's kitchen within an hour of being picked". See, for example, Ocado Group: "Ocado brings its innovation and automation expertise to sustainable vertical farming", 10 June 2019.
28. Prabhu, Jawaharlal Nehru Professor of Indian Business and Enterprise at Cambridge Judge Business School, has argued that around four billion people, not all of them in developing countries, lack sufficient access to food. "The big challenge," he has said, "is how to meet their needs without wrecking the planet." See, for example, Prabhu, J: Frugal Innovation: How to Do More With Less, 2015.
29. See AgFunder: AgFunder Farm-Tech Investment Report 2021, 2021.
30. See Amelung, W, Bossio, D, de Vries, W, Kögel-Knabner, I, Lehmann, J, Amundson, R, Bol, R, Collins, C, Lal, R, Leifeld, J, Minasny, B, Pan, G, Paustian, K, Cumpel, C, Sanderman, J, van Groenigen, J, Mooney, S, van Wesemael, B, Wander, M, and Chabbi, A: Towards a Global-Scale Soil Climate Mitigation Strategy, 2020.
31. See World Economic Forum: "Why the agtech boom isn't your typical disruption", 25 February 2019.
32. See AppHarvest: Feed the Future: Annual Public Benefit Corporation Report, Fiscal Year 2020, 2021.
33. Other agtech businesses that have adopted the SPAC route include Benson Hill, Gingko Bioworks, AeroFarms and Local Bounti. See Forbes: "Farmtech investing is accelerating faster than foodtech and general VC – new report", 29 July 2021.
34. See AppHarvest: Feed the Future: Annual Public Benefit Corporation Report, Fiscal Year 2020, 2021.
35. See Motley Fool: "An interview with AppHarvest founder and CEO Jonathan Webb", 4 June 2021.
36. Perhaps most infamously, Make Room! Make Room! – later turned into a cult movie, Soylent Green – depicted a future in which a sinister mega-corporation secretly turned human remains into food. See Harrison, H: Make Room! Make Room!, 1966.

Important information

Risk warnings

The value of investments and any income will fluctuate (this may partly be the result of exchange rate fluctuations) and investors may not get back the full amount invested. The use of environmental, social and governance factors to exclude certain investments for non-financial reasons may limit market opportunities available to funds not using these criteria. Further, information used to evaluate environmental, social and governance factors may not be readily available, complete or accurate, which could negatively impact the ability to apply environmental, social and governance standards.

This marketing communication is for Professional Clients only in Dubai, Jersey, Guernsey, Isle of Man, Ireland, Continental Europe (as defined in the Important Information at the end) and the UK; for Sophisticated or Professional Investors in Australia; Institutional Investors in the United States; for wholesale investors (as defined in the Financial Markets Conduct Act) in New Zealand; for accredited investors as defined under National Instrument 45-106 in Canada; for Qualified Institutional Investors in Japan; for Professional Investors in Hong Kong; for Institutional/Accredited Investors in Singapore; for Qualified Institutions/Sophisticated Investors in Taiwan; for Qualified Clients/Sophisticated Investors in Israel; It is not intended for and should not be distributed to or relied upon by the public or retail investors. Please do not redistribute this document.

For the distribution of this document, Continental Europe is defined as Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Liechtenstein, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.

By accepting this material, you consent to communicate with us in English, unless you inform us otherwise. This document is marketing material and is not intended as a recommendation to invest in any particular asset class, security or strategy. Regulatory requirements that require impartiality of investment/investment strategy recommendations are therefore not applicable nor are any prohibitions to trade before publication. The information provided is for illustrative purposes only, it should not be relied upon as recommendations to buy or sell securities. All material presented is compiled from sources believed to be reliable and current, but accuracy cannot be guaranteed. This is not to be construed as an offer to buy or sell any financial instruments and should not be relied upon as the sole factor in an investment making decision.

As with all investments there are associated inherent risks. This should not be considered a recommendation to purchase any investment product. This does not constitute a recommendation of any investment strategy for a particular investor. Investors should consult a financial professional before making any investment decisions if they are uncertain whether an investment is suitable for them. Please obtain and review all financial material carefully before investing. Past performance is not indicative of future results. The opinions expressed are those of the author, are based on current market conditions and are subject to change without notice. These opinions may differ from those of other Invesco investment professionals. Where individuals or the business have expressed opinions, they are based on current market conditions, they may differ from those of other investment professionals, they are subject to change without notice and not to be construed as investment advice. These materials may contain statements that are not purely historical in nature but are "forward-looking statements." These include, among other things, projections, forecasts, estimates of income, yield or return or future performance targets. These forward-looking statements are based upon certain assumptions, some of which are described herein. Actual events are difficult to predict and may substantially differ from those assumed. All forward-looking statements included herein are based on information available on the date hereof and Invesco assumes no duty to update any forward-looking statement. Accordingly, there can be no assurance that estimated returns or projections can be realized, that forward-looking statements will materialize or that actual returns or results will not be materially lower than those presented.

Restrictions on distribution

Australia

This document has been prepared only for those persons to whom Invesco has provided it. It should not be relied upon by anyone else. Information contained in this document may not have been prepared or tailored for an Australian audience and does not constitute an offer of a financial product in Australia. You may only reproduce, circulate and use this document (or any part of it) with the consent of Invesco.

The information in this document has been prepared without taking into account any investor's investment objectives, financial situation or particular needs. Before acting on the information the investor should consider its appropriateness having regard to their investment objectives, financial situation and needs.
You should note that this information:
may contain references to dollar amounts which are not Australian dollars;

- may contain financial information which is not prepared in accordance with Australian law or practices;
- may not address risks associated with investment in foreign currency denominated investments; and does not address Australian tax issues.
- Issued in **Australia** by Invesco Australia Limited (ABN 48 001 693 232), Level 26, 333 Collins Street, Melbourne, Victoria, 3000, Australia which holds an Australian Financial Services Licence number 239916.

Canada

This document is restricted to accredited investors as defined under National Instrument 45-106. All material presented is compiled from sources believed to be reliable and current, but accuracy cannot be guaranteed. This is not to be construed as an offer to buy or sell any financial instruments and should not be relied upon as the sole factor in an investment making decision. As with all investments there are associated inherent risks. Please obtain and review all financial material carefully before investing.

- Issued in **Canada** by Invesco Canada Ltd., 120 Bloor Street East, Suite 700, Toronto, Ontario, M4W 1B7.

Continental Europe, Dubai, Ireland, the Isle of Man, Jersey and Guernsey and the UK

The document is intended only for Professional Clients in Continental Europe, Dubai, Ireland, the Isle of Man, Jersey, Guernsey, and the UK and is not for consumer use. Marketing materials may only be distributed without public solicitation and in compliance with any private placement rules or equivalent set forth in the laws, rules and regulations of the jurisdiction concerned. This document is not intended to provide specific investment advice including, without limitation, investment, financial, legal, accounting or tax advice, or to make any recommendations about the suitability of any product for the circumstances of any particular investor. You should take appropriate advice as to any securities, taxation or other legislation affecting you personally prior to investment. No part of this material may be copied, photocopied or duplicated in any form by any means or redistributed without Invesco's prior written consent.

Further information is available using the contact details shown:

- Issued in **Belgium, Denmark, Finland, France, Ireland, Greece, Italy, Netherlands, Spain, Sweden, Luxembourg, Norway** and **Portugal** by Invesco Management S.A., President Building, 37A Avenue JF Kennedy, L-1855 Luxembourg, regulated by the Commission de Surveillance du Secteur Financier, Luxembourg.
- Issued in **Dubai** by Invesco Asset Management Limited. PO Box 506599, DIFC Precinct Building No 4, Level 3, Office 305, Dubai, UAE. Regulated by the Dubai Financial Services Authority.
- Issued in **Austria** and **Germany** by Invesco Asset Management Deutschland GmbH, An der Welle 5, 60322 Frankfurt am Main, Germany.
- Issued in **Switzerland** by Invesco Asset Management (Schweiz) AG, Talacker 34, 8001 Zurich, Switzerland.
- Issued in **the Isle of Man, Jersey, Guernsey** and the **United Kingdom** by Invesco Asset Management Limited which is authorised and regulated by the Financial Conduct Authority. Invesco Asset Management Ltd, Perpetual Park, Perpetual Park Drive, Henley-on-Thames, RG9 1HH, UK.

Hong Kong

This document is provided to professional investors (as defined in the Securities and Futures Ordinance and the Securities and Futures (Professional Investor) Rules) only in Hong Kong. It is not intended for and should not be distributed to or relied upon by the members of public or the retail investors.
written consent.

- Issued in **Hong Kong** by INVESCO HONG KONG LIMITED 景順投資 管理有限公司, 41/F, Champion Tower, Three Garden Road, Central, Hong Kong.

Israel

This document may not be reproduced or used for any other purpose, nor be furnished to any other person other than those to whom copies have been sent. Nothing in this document should be considered investment advice or investment marketing as defined in the Regulation of Investment Advice, Investment Marketing and Portfolio Management Law, 1995 ("the Investment Advice Law"). Investors are encouraged to seek competent investment advice from a locally licensed investment advisor prior to making any investment. Neither Invesco Ltd. nor its subsidiaries are licensed under the Investment Advice Law, nor does it carry the insurance as required of a licensee thereunder.

- Issued in **Israel** by Invesco Asset Management Limited, Perpetual Park, Perpetual Park Drive, Henley-on-Thames, Oxfordshire, RG9 1HH, United Kingdom. Authorised and regulated by the Financial Conduct Authority.

Japan

This document is only intended for use with Qualified Institutional Investors in Japan. It is not intended for and should not be distributed to, or relied upon, by members of the public or retail investors.

- Issued in **Japan** by Invesco Asset Management (Japan) Limited, Roppongi Hills Mori Tower 14F, 6-10-1 Roppongi, Minato-ku, Tokyo 106-6114; Registration Number: The Director-General of Kanto Local Finance Bureau *(Kin-sho)* 306; Member of the Investment Trusts Association, Japan.

New Zealand

This document is issued only to wholesale investors (as defined in the Financial Markets Conduct Act) in New Zealand to whom disclosure is not required under Part 3 of the Financial Markets Conduct Act. This document has been prepared only for those persons to whom it has been provided by Invesco. It should not be relied upon by anyone else and must not be distributed to members of the public in New Zealand. Information contained in this document may not have been prepared or tailored for a New Zealand audience. You may only reproduce, circulate and use this document (or any part of it) with the consent of Invesco. This document does not constitute and should not be construed as an offer of, invitation or proposal to make an offer for, recommendation to apply for, an opinion or guidance on Interests to members of the public in New Zealand. Any requests for information from persons who are members of the public in New Zealand will not be accepted.

- Issued in New Zealand by Invesco Australia Limited (ABN 48 001 693 232), Level 26, 333 Collins Street, Melbourne, Victoria, 3000, Australia, which holds an Australian Financial Services Licence number 239916.

Singapore

This document may not be circulated or distributed, whether directly or indirectly, to persons in Singapore other than (i) to an institutional investor under Section 304 of the Securities and Futures Act (the "SFA"), (ii) to a relevant person pursuant to Section 305(1), or any person pursuant to Section 305(2), and in accordance with the conditions specified in Section 305 of the SFA, or (iii) otherwise pursuant to, and in accordance with the conditions of, any other applicable provision of the SFA. This document is for the sole use of the recipient on an institutional offer basis and/or accredited investors and cannot be distributed within Singapore by way of a public offer, public advertisement or in any other means of public marketing.

- Issued in **Singapore** by Invesco Asset Management Singapore Ltd, 9 Raffles Place, #18-01 Republic Plaza, Singapore 048619.

Taiwan

This material is distributed to you in your capacity as Qualified Institutions/Sophisticated Investors. It is not intended for and should not be distributed to, or relied upon, by members of the public or retail investors.

- Issued in **Taiwan** by Invesco Taiwan Limited, 22F, No.1, Songzhi Road, Taipei 11047, Taiwan (0800-045-066). **Invesco Taiwan Limited is operated and managed independently.**

United States

- Issued in the **US** by Invesco Advisers, Inc., Two Peachtree Pointe, 1555 Peachtree Street, N.E., Suite 1800, Atlanta, GA 30309.