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The food revolution

The future of food and the challenges we face

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The food revolution
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Foreword

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Food is life. Producing it has reshaped our planet. Today, whole economies and even national security depend on it.

Yet the current agricultural system is unsustainable. Agriculture already accounts for most of our water and a high percentage of our land use, as well as the bulk of human-generated greenhouse gases. With resources dwindling, the challenge of how to feed a growing, urbanizing population without further damaging the earth is only intensifying.

A lasting solution will require a substantial rethink about how we as a society live and grow our food. The transition to a new system will not be easy. Here, the good news is that an agricultural revolution is at hand, powered by the technologies of the Fourth Industrial Revolution. Sweeping innovations, including trends in vertical farming, aquaculture, biotech, blockchain, and robotics, are transforming the way we produce food and will continue to do so for some time.

But the principal disruptive force is the consumer. In some cultures, tastes are moving away from animal to plant-based proteins. As we highlight, this move is being funded by some of the wealthiest individuals and corporations in the world.

It's just the beginning, but we're excited about the change and disruption ahead. We envision rapid expansion in areas like alternative meat, Farming 4.0, online food delivery, and seed treatment and science. For the agriculture industry as a whole, we see the technology segment jumping from a market size of USD 135bn today to around USD 700bn by 2030, representing a 15% compound annual growth rate.

The future of food helps investors contribute to positive change while seeking long-term returns. In start-ups and the business divisions of major food conglomerates alike, appealing opportunities are arising as financiers of bold new ideas aim to remake the food system model from a resource-intensive one into a fully sustainable one. In the following pages, we analyze the current system and examine the sweeping changes that lie ahead. In our view, there is no better time to invest in food and agriculture than now.

We also hope this report prompts readers to consider the incredible global effort involved in bringing food to their dinner table and how all of that is about to change. We hope you enjoy reading *The food revolution* and welcome your feedback.

Regards,

Mark Haefele Min Lan Tan

Executive summary

Source: Getty Images

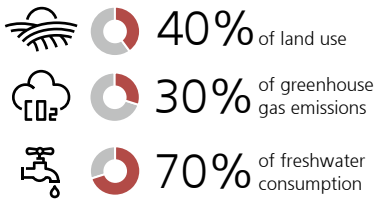
- We need to **completely transform our global food production system** to meet consumers' evolving need for healthy nutritious food for all, and conserve our planet's precious resources for future generations. Food production already accounts for most of our water and a high percentage of our land use, as well as the bulk of human-generated greenhouse gases.

- However, we face the challenge of **urban populations** to feed, fuel, and clothe with increasingly limited resources available – whether it's land, soil, water, nutrients, or labor. Also, the rapidly changing climate – due to increasingly unbridled human activity – is influencing the natural limitations of the planet.

- The good news is that we are on the cusp of a **new agricultural revolution** that will likely reshape the way we farm, ship, and consume food. Change is being driven by **five megatrends:** 1) The political economy under scarcity; 2) the new-age consumer; 3) health and wellness; 4) digital catch-up; and 5) sustainable living.

- There are numerous new technologies that can be applied to raising agricultural productivity, safeguarding environmental health, and satisfying evolving consumer preferences. They include **biological solutions** with improved environmental safety and completely new approaches that improve yield and increase natural plant resistance to diseases and pests. Innovations like **vertical farming, lab-grown food,** and **algae aquaculture,** and the components of the **Fourth Industrial Revolution** (big data, Internet of Things, artificial intelligence) are being integrated throughout the agriculture supply chain.

Food production globally accounts for



Source: United Nations

Source: Getty Images

- Until recently, agriculture lagged all other industries in terms of disruption. **Digital penetration** in the field was just 0.3% in 2018 compared to 2.5% for financials and close to 12% for retail. But this figure is set to spike – investment in agriculture-related technology hit USD 16.9bn last year, up 43% from 2017, according to AgFunder. Given the vast, untapped market and the rapid emergence of powerful technologies, we expect food innovation to become a **USD 700bn market by 2030** – a fivefold jump from today. To benefit from rapidly growing segments and the topic's long-term potential, we advise investors to diversify exposure among unlisted and listed companies.

- For investors, **notable opportunities** can be found in select segments. The plant-based protein segment, for which we expect a CAGR of 28% by 2030 (from USD 4.6bn in 2018 to USD 85bn), holds vast potential. We also forecast vibrant growth rates for the smart farming (16%), online food delivery (16%), seed treatment (13%), and seed science (9%) segments over this time period.

- On their own, major agri-corporations can't solve all the issues faced by the agriculture industry. It will take a coalition that includes non-traditional investors, entrepreneurs, growers, and governments to meet the challenges ahead. **While the future is promising, it's not guaranteed.**

- To move forward, we need to bust the lingering myth that technology is the enemy of natural, abundant, affordable food. Small farm owners need to adapt to the times by adopting new technologies. This need extends around the world, and **open access to the latest innovations** is vital. To ensure they do, the entire industry has to come together and agree on ways to achieve set objectives like the **UN's Sustainable Development Goals.** By investing for both profits and good, we can make a tangible, positive difference in how the world farms and eats.

Food for thought

We need to bust the lingering myth that technology is the enemy of natural, abundant and affordable food.

Chapter 1

On the cusp of revolution

The challenge is how to feed a growing population without destroying our planet.

The UN predicts the global population will swell from less than eight billion today to around 10 billion in the next three decades. Over the next 10 years or so, roughly 1 billion people will enter the middle class. Growing healthy food in a sustainable way for such a vast number of people requires rethinking our current approach to the food supply chain and applying technology intelligently to enhance what nature already offers.

To do so, we first need to bust the lingering myth that technology is the enemy of natural, abundant, nutritional and affordable food. After all, technology is the only way to secure the nutrition needed without destroying the planet. The good news is that we are on the cusp of a global food revolution. Transformational change, in our view, is about to occur across every aspect of how the sector works and what it produces.

Unlike revolutions of the past, this time people – not companies or governments – are driving it. And investors should pay close attention; the food industry needs to focus on integrating the breakthroughs of the "Fourth Industrial Revolution," not spend time re-inventing the wheel.

Source: Sarah Martin

Farmer with combined harvester on field.

Wayne Gordon, one of the authors of this report, shares his personal view on how farming has evolved over the years.

I come from a line of farmers who trace their roots back more than a century. My siblings and I were raised on our farm, and my children play in the fields and on our tractors during summer. My parents, grandparents, and great-grandparents have struggled through bust and rejoiced in boom years. For over a century, our outlook has always been harvest to harvest. But we're now being forced to look much longer term. Climate change is shortening planting seasons, subjecting our crops to mounting pressure from erratic rain cycles, and traditional farming practices are less effective.

These irreversible trends offer us a simple choice: adapt and thrive or carry on and wilt. We've chosen the former path. By integrating new technologies into our production process, we've been able to boost yields and withstand the increasing variability of the weather. Yet this is just the beginning. The world is starting to wake up to the reality that our current food system is unsustainable and that action is urgently needed.

Gordon family farm, Australia, c. 1920s

Gordon family farm, Australia, 2018

Food for thought

The challenge is no longer just about ending hunger.

Source: Getty Images

Food vs. nutritional security

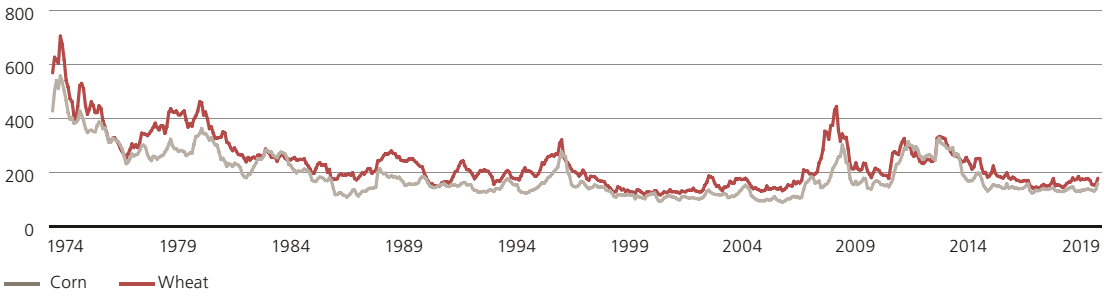
In recent decades the worldwide population expansion and the rise of the middle class with its appetite for meat, dairy and high-calorie foods have continually raised demand for crops. Nonetheless, this sustained demand growth hasn't spurred an agricultural super-cycle or structurally higher prices for staples, as many predicted it would. In fact, in real terms, prices have fallen and many farmers still live at subsistence levels.

In other industries, booming demand has unlocked vast wealth for producers. Why hasn't this occurred in agriculture? It's simple – the industry has trapped itself in a vicious cycle. To meet demand, farmers have greatly boosted production of crops by adopting precision agriculture and genetically modified plants. Furthermore, countries in the former Soviet Union and South America which were previously lost-cost sources of land and labor have now rapidly industrialized. The result has been an unimaginable bounty of produce, but one that has come at the expense of smallholding farmers' incomes and the environment.

Of greater importance is the distinction between food security and nutritional security as the challenge is no longer just about ending hunger. The UN estimates that the obese now outnumber the chronically underfed, and one-third of all food grown is being wasted. A Lancet Commission (2019) report estimates that, worldwide, unhealthy diets account for up to one in five premature deaths every year.

Inflation-adjusted grain prices remain near historical lows

In USD/ton



Source: Bloomberg, UBS

Food for thought

11% of the world's remaining natural areas could be lost by 2050 due to the conversion of land for agricultural use.

Source: Getty Images

Traditional models are unsustainable

The current agricultural business model has to take some responsibility for the untenable state of affairs today. In their quest to produce ever more food, farmers have been incentivized to disregard environmental costs, leading to a depletion of biodiversity, pollinators (e.g. bees) and soil health, as well the social costs associated with scarce resources like water and energy. According to the UN, food production around the world currently accounts for 40% of land use, 30% of greenhouse gas (GHG) emissions and 70% of freshwater consumption.

Moreover, the UN's Food and Agriculture Organization (FAO) believes one-quarter of the world's farmland has been rated as highly degraded and another 44% is moderately or slightly degraded. A study by the Economics of Ecosystems and Biodiversity estimates that 11% of earth's remaining natural areas could be lost by 2050 due to the conversion of land for agricultural use.

Expanding food production further carries with it potentially devastating costs. Simply put, we are nearing the world's natural limits. And, according to the FAO, the agricultural land area will remain relatively unchanged in the coming decades. So yield improvements from the same amount of land will need to account for the majority of the productivity increase.

Food production globally currently accounts for...

Source: United Nations

Food for thought

People are now demanding a new way of producing food and are forcing the industry's hand through their spending decisions.

Source: Getty Images

People affecting change

Awareness is spreading about the grave impact the current agricultural production model has had on the planet and society. People are now demanding a new way of producing food and are forcing the industry's hand through their spending decisions. And farmers are the first to agree that the rules of the game need to change. After all, they have the most to gain from revamping the economics of agriculture and the most to lose if the current setup endures.

Until now, multinational corporations have exerted tremendous influence on what people eat and how staple food and food ingredients are procured and transported. They have controlled the information and the business model. But shifting demand patterns are disrupting the industry and forcing big food companies and traders to scramble to stay ahead of consumers. Companies are now facing the same choice as farmers: adapt or risk being left behind.

From the popularity and stock market success of Beyond Meat, the veggie burger maker, through the meteoric rise in demand for organic produce to the spread of vegan and gluten-free diets, interest in where our food comes from has never been greater. Another example of consumer-led change is the shift away from foods with added sugar. Sugar taxes are becoming more frequent – the UK levied a tax on drinks containing 8 grams of sugar or more per 100ml in 2018, for instance – and demand for it has been falling steadily in recent years.

Food for thought

Access to nutritious food will be a defining issue of the 21st century.

Source: Getty Images

Inclusion, the essential ingredient

Investors, big producers, and progressive farmers are getting on board by adopting "Fourth Revolution" technology like computer vision, robotics, data science, and machine learning, which is making the critical leap from the labs to fields. But we're a far cry from its use by ordinary farmers, which raises the question: What will it take for smallholders to embrace it?

Strengthening innovation uptake in emerging markets is essential because much of the growth in supply and demand will come from these regions. Success will require excellent digital execution as many of these markets are coming of age in the digital age. Moreover, companies will need to bring their newest, most advanced equipment and thinking – not last-generation, lower-quality products – into developing markets, while investors and consumers alike can influence success or failure via their wallets.

It's evident to us that access to nutritious food will be a defining issue of the 21st century. The UN, for one, is taking this challenge seriously. Its Sustainable Development Goals (SDGs) put forward not only a vision for sustainable production and consumption but for ending poverty and hunger as well.

Source: Johnny Frog

Source: Ailine Liefeld

What will we eat in 20 years?

There were few vegans 20 years ago; there are many millions today, and their number is rising worldwide. Mock meat was an almost comical fad 20 years ago; it's no laughing matter today, given the industry's meteoric rise in recent years. People will always need sustenance, but tastes and diets are changing. By 2030, it's likely that these trends will continue to develop and new ones will dominate the culinary zeitgeist.

Indeed, the food we eat and the beverages we drink today may not be the same as those tomorrow. The World Economic Forum (WEF) envisions a period of rapid innovation in our ability to fuse physical, digital and biological technologies. Perhaps in 2030 we'll buy meat based on laboratory of origin instead of country. The potential to disrupt the foundations of our everyday lives is real, and the food sector will not be immune to it.

The food industry needs to reshape itself to meet the new realities. As increased awareness of climate change has driven a critical mass of conscious consumers to rally for better, environmentally friendlier alternatives to fossil fuels, the same thing needs to happen in food production. All of us will have to embrace change and avoid building walls around traditional segments and techniques to preserve the status quo.

How will the nature of food production change? What new techniques will be used and what new products grown? How will supply chains adapt? These questions are the main themes we explore in this report. What we do know is that the technology needed to revolutionize the food system already exists. The trouble is that it's being developed in silos with limited integration.

The primary challenge for any technology is to appeal to end users – in this case, producers, processors, and consumers. Only when digital solutions prove to be more practical, efficient, and affordable than anything else on the market will agriculture enjoy its smartphone moment.

Source: Ailine Liefeld

The success of a budding industry is not the only thing at stake here. So is the very health of the planet. The food industry needs to think near and long term at once, and adopt a practical idealism. As noted broadcaster, writer, and naturalist Sir David Attenborough has aptly said: "We have to recognize that every breath of air we take, every mouthful of food we take, comes from the natural world."

We begin the report by briefly recapping the enduring megatrends as they relate to food. We then explore some of the emerging innovations that should be on investors' radar. We highlight new forms of food such as algae and printed, cultured, and plant-based products. And we examine the different ways these products will be grown, processed, and distributed.

"We have to recognize that every breath of air we take, every mouthful of food we take, comes from the natural world."

David Attenborough – Noted broadcaster, writer, and naturalist

Chapter 2

The mega-trends reshaping food under scarcity

Change is happening across the board, principally led by consumers.

Source: Getty Images

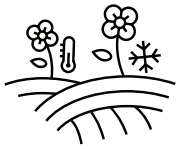
Mega trends are a distinct group of powerful social, demographic, environmental and technological forces of change that are reshaping our world. We believe the following five trends will shape the food industry in the coming decades.

Trend 1: The political economy under scarcity

Trend 2: The new-age consumer

Trend 3: Health and wellness

Trend 4: Digital catch-up



Trend 5: Sustainable living

Trend 1: The political economy under scarcity

Our demographic future is well known: about 2 billion extra people will live on the planet by 2050, and global demand for food is expected to increase roughly 60% in the period (UN, 2019). Among the shifts from west to east and north to south that will occur, food demand is one. Population growth in Asia and Africa will outstrip that of the world as a whole. Africa alone will add another 1 billion people by 2050, while Asia will become vastly more urban (by 2030, Asia will have nearly half of the world's urban residents). The UN forecasts 2.5 billion more city dwellers in it and in Africa by midcentury.

As countries urbanize, food production changes, and the decisions about how to allocate resources between urban and rural areas become more complex and political. Water scarcity, for example, will become a key issue as national interests diverge. Competition for land will also affect trade in food and value chains, and poor infrastructure in developing countries means domestic food production will struggle to meet increased domestic demand, while middle class urban residents' preferences could shift towards imported food if it is cheaper and of higher quality.

While food security has often been defined on the grounds of self-sufficiency, this characterization is changing to include resilience, diversity, and affordability. In Asia, as a case in point, the rise in demand for food has made it difficult for most countries, particularly China, to remain self-sufficient. What's more, greater resource scarcity augments the need for a virtual exchange of water and land – the open and efficient global food supply chains. With rising trade threats, alliances and regional-based trade agreements are gaining in importance; this exchange becomes more complex as does the risks of a mismatch between supply and demand.

Tariff wars are poison to the trade-dependent food sector. But as tensions have risen between the US and several countries/regions, including China, Canada, Mexico and the EU, tit-for-tat tariffs have become more prevalent, altering long-established agricultural trade routes. For example, China has turned to Brazil for soybeans and pork imports and to Australia for beef and cotton, all previously sourced from the US. Predictably, these disruptions erode the benefits of global trade in terms of food access, nutrition and efficiency.

While the outcomes of the current dispute remain uncertain, what's clear is that regional governments will pay greater attention to national food security strategies and these policies will define food production and supply chain trends in the next decade or so. The size and composition of strategic food inventories are one visible way this will manifest itself; for instance, China's strategic corn reserves are reported to cover more than seven months of consumption. Also, local food production levels and subsidies, and land acquisition strategies are others; for example, transaction data suggests that China and Saudi Arabia have made major agricultural land acquisitions in countries like Australia in recent years.

Part of the US's trade dispute with China is intellectual property theft. By extension, a breakdown of systems to share technology and a lack of trained people to use the information it gathers are major constraints to food security, particularly in developing countries. The need for international cooperation to share information, innovation and technology is more relevant in food production today than in any other industry.

1 NO POVERTY

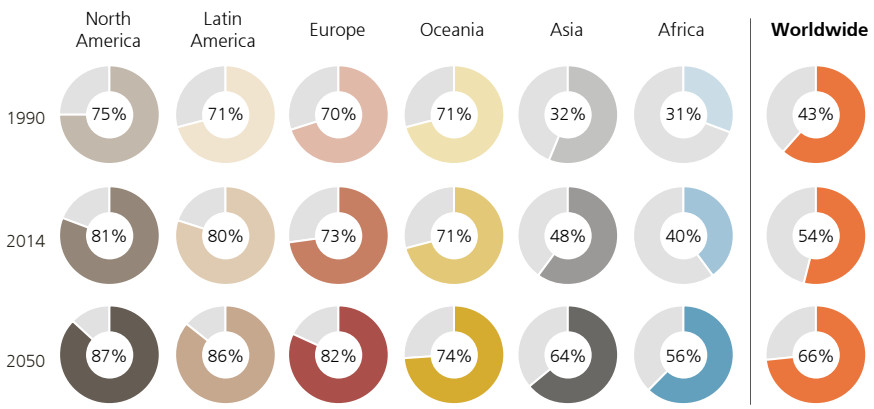
16 PEACE, JUSTICE AND STRONG INSTITUTIONS

No.1: No poverty. About three-quarters of the extreme poor live in rural areas, with most dependent on agriculture for their livelihoods and food security. An inclusive agricultural sector can create jobs and eliminate hunger in rural areas.

No. 16: Peace, Justice and strong institutions. Food security and a healthy agricultural sector can play a critical role in preventing conflict and distress migration, and in building peace.

54% of the world's population now lives in cities

% of the population living in urban areas



Source: United Nations

Major demographic shifts

By 2050

2 billion

extra people are expected

+60%

increase in global food demand

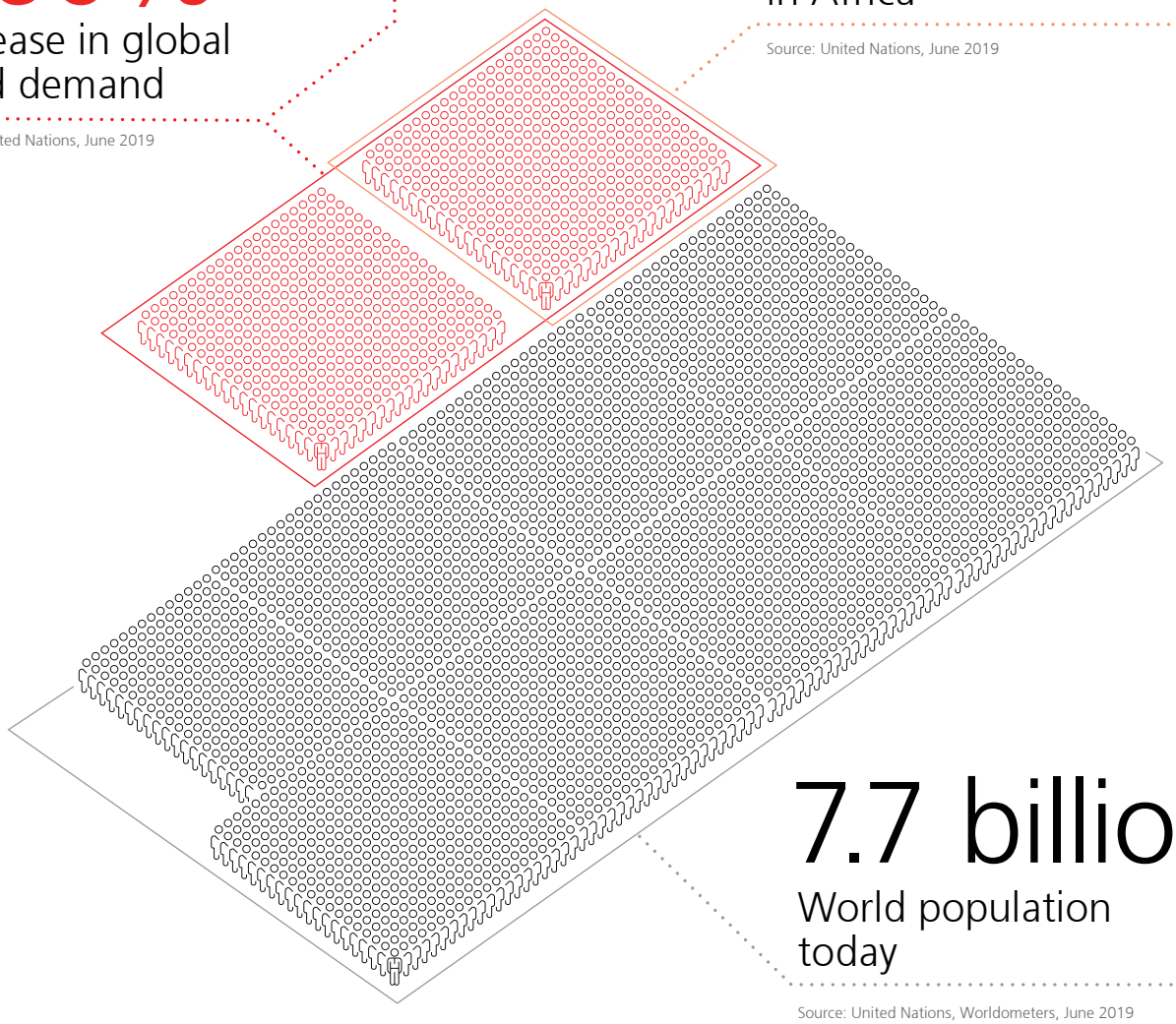
Source: United Nations, June 2019

By 2050

1.05 billion

more people are expected in Africa

Source: United Nations, June 2019



7.7 billion

World population today

Source: United Nations, Worldometers, June 2019

Food for thought

The UN predicts the global population will swell from less than 8 billion today to around 10 billion in the next three decades. Over the next 10 years or so, roughly 1 billion people will enter the middle class.

Trend 2: The new-age consumer

What will midcentury consumers look like? What will they buy and how will they consume it? The answers to these questions will be shaped by three demographic groups – new Asian urbanites, graying Gen Xers and millennials. Overall, consumers, from here, will be a hyper-connected group of individuals who instantly access the latest solutions via various digital platforms. Overall, consumers want to feel closer to their food, while urbanization takes them farther away – technology and innovation will be increasingly called upon to bridge this gap.

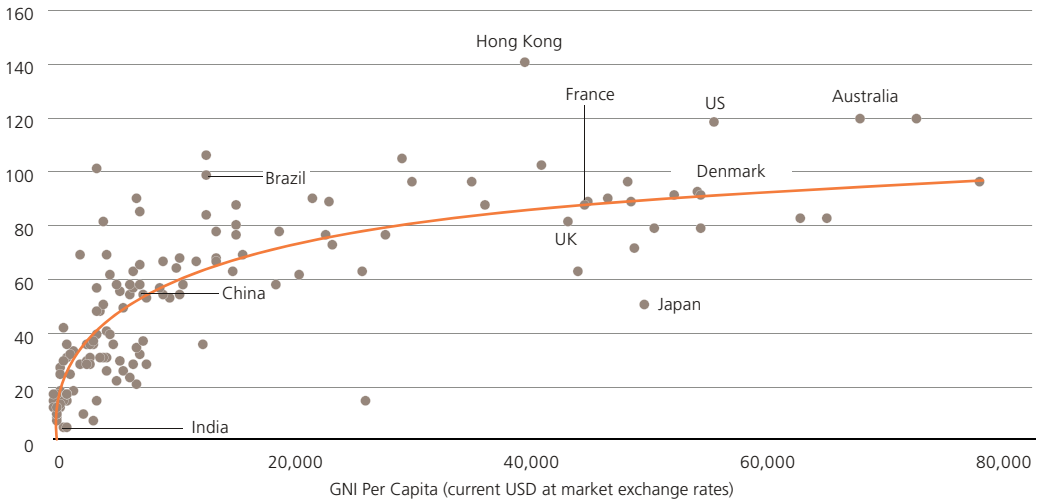
Source: Getty Images

If all goes smoothly, urbanization, income growth and greater food availability through trade should see a broadening out of diets, particularly in higher-value categories of food. But this is not without consequences; for example, as consumers move toward more energy-dense diets, current resources will become increasingly stretched. Basically, people eat more cereals indirectly through meat.

We acknowledge one size doesn't fit all as the trend towards increased protein consumption manifests itself differently based on religious belief, custom, and/or the presence of a strong vegetarian culture, as in India. But, as a general rule, like Western countries, Asia will pivot further toward the double burden of undernutrition and obesity in the future without adequate circuit breakers.

Per capita meat consumption

In kg/year



Source: FAO, World Bank and Nomura Global Economics

Food for thought

According to Deloitte, by 2020 millennials will make up 40% of all consumers, influencing about USD 40bn in annual sales.

Furthermore, these demographic shifts also disrupt how food will be consumed in the future; designing of products to appeal to different age groups will be half the battle for traditional food companies. Whether it is a digital platform aimed at providing millennials immediate access to products and services (like food delivery apps) or solutions designed to complement the lifestyles of aging baby boomers (like vitamin supplements and wellness services), each niche will need careful planning and execution.

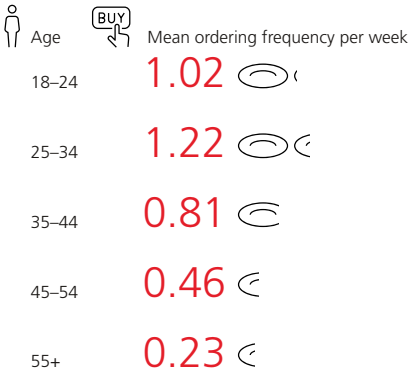
Millennial consumers are adopting digital solutions that provide instant access to products and services they want without being confined to physically nearby choices, such as apps like GrubHub, Deliveroo and Uber Eats. According to recent McKinsey research, unlike their predecessors, consumers under the age of 35 tend to differ fundamentally in ways that make mass brands and traditional channels ill-suited to them. They tend to prefer new brands, especially in food products; the rising popularity of Beyond Meat and Impossible Burger is one example. In fact, according to KPMG (2019), millennials are almost four times likelier than baby boomers to avoid buying products from multinational food companies.

As part of this shift, this group increasingly shows a preference toward "mindful eating" – that is, choosing brands and foods that come from sustainable sources – and a conscious engagement with the food industry, and how food is produced and the way it is consumed. According to Deloitte, by 2020 millennials will make up 40% of all consumers, influencing about USD 40bn in annual sales.

Aging demographic populations are also a consideration of the supply side (and not just in developed nations). Urbanization and aging have serious implications for the composition of the rural labor force, patterns in agricultural production, the social cohesion of rural communities, and property rights. Of the 570 million farms in the world, only 4% are in high-income countries while 49% are in lower-income ones (FAO, 2017).

Source: Getty Images

Online food delivery demand driven by young consumers



Source: UBS Evidence Lab, as of 2018

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

No.12: Responsible consumption and production. Waste minimization is a global challenge. The UN estimates 1.3 billion tons of food is lost or wasted annually, equating to roughly one-third of global food production.

Trend 3: Health and wellness

According to KPMG, the health and wellness industry is already valued at almost USD 769bn, or approximately 30% of the global packaged food market. For years, consumers have said that they wanted to eat healthier foods and live healthier lifestyles, but their behavior did not change - until now. The World Health Organization (WHO) estimates that about 80% of premature heart disease cases, strokes and incidences of type-2 diabetes, as well as 40% of cancers, could be avoided if major risk factors for non-communicable diseases, such as unhealthy diets, were eliminated.

The costs associated with poor diets high in fatty processed foods are enormous – the World Obesity Federation (WOF) estimates this to be USD 850bn in direct healthcare costs alone. One in five adults and one in six children in OECD countries are obese. If action is not taken soon, the medical bill for treating the health complications associated with obesity is expected to climb to USD 1.2trn by 2025 (WOF, 2018). Prevention is the focus as consumers redefine what a healthy diet means: more natural, green, organic products and/or food that is free of sugar, gluten, pesticides, and other additives. Moreover, the demand for highly personalized health and the wearing of fitness trackers etc. is experiencing rapid adoption. In fact, greater data into the impacts of one's eating habits versus nutrition requirements are reinforcing the trends in personalized nutrition.

Likewise, policy-makers are increasingly aware of this strong link between diet (along with the environment) and health. Already, we hear of policy-makers reviewing dietary guidelines and the international medical community, which is building a case for reducing the amount of red meat eaten, and promoting the increase of plant-based protein in society's diet. Food that specifically addresses personal health concerns – such as fare that contains anti-inflammatory properties or nutrient-dense ingredients that support immune functions, and those that improve overall gut health – is also skyrocketing in popularity. A greater diversification of diet is another driver of better health, according to the WHO. This is the main argument of producers who are reviving the cultivation of these traditional but often forgotten food crops. As an example, Timeless Seeds sells only heirloom varieties of grains and legumes that are good rotation crops for replenishing soil.

Source: Anita Affentranger

Food for thought

The World Health Organization (WHO) estimates that about 80% of premature heart disease cases, strokes and incidences of type-2 diabetes, as well as 40% of cancers, could be avoided if major risk factors for non-communicable diseases, such as unhealthy diets, were eliminated.

2 ZERO HUNGER

No.2: Zero Hunger.
Food production will need to increase by an estimated 50% by 2050 to meet the needs of almost 10 billion people on the planet. Already, roughly 820 million people are chronically undernourished.

3 GOOD HEALTH AND WELL-BEING

No.3: Good health and wellbeing.
Good health starts with nutrition. A Lancet Commission (2019) report estimates that worldwide unhealthy diets account for up to one in five premature deaths every year.

Can better diets help the environment?
It depends. Altering diets to be more plant-based or "flexitarian" and its related health benefits are definitely a better ideological fit in terms of sustainability. Earlier this year, the EAT Lancet Commission released a report on the impact that diet can have on the environment. Based on an analysis of scientific evidence, it concluded that consumers need to transition their diet from animal to plant-based proteins to help mitigate the increase in greenhouse gases (GHG). Many consumers buy organic foods citing reasons related to health and the method as better for the environment and biodiversity overall. Organic food sales in the US tell the story, having doubled in the last decade, according to the National Geographic (2018).

However, a paradox arises. While organic food is seen as the source of better health, a comprehensive review of 237 studies conducted by Stanford University found no health benefits over conventionally-grown foods. Stir in the various competing interest groups who offer conflicting claims about organic and non-organic food, and it's not surprising that many consumers are left feeling confused and distrustful.

Finding ways to farm more sustainably to provide safe, abundant and nutritious foods to a rapidly growing world is a challenge that only science can solve. We need to educate groups, particularly millennials. Scientists need to reassure the public that they have nothing to fear about today's agricultural technologies, and that ignoring these new products comes with costs to their wellbeing and to the environment. As an example, the next generation of seed technology is focused on health and functional foods.

Australia's national science agency (CSIRO) has developed canola that produces high-quality vegetable oil rich in omega-3 docosahexaenoic acid (DHA), fish being the closest alternative. Avoiding this technology potentially reduces the intake of Omega 3 and maintains our reliance on fish as a source when according to the FAO 30% of the world's fisheries are overfished.

Source: Nordwood Themes, Unsplash

Food for thought

Consumers need to transition their diet from animal to plant-based proteins to help mitigate the increase in greenhouse gases.

Trend 4: Digital catch-up

We believe the food and agriculture industry is on the cusp of digital revolution. As recently as 2018 food production ranked dead last in terms of adopting digital technologies – for example, digital penetration in agriculture is 0.3%, versus 2.5% for financials and close to 12% for retail. But today it's drawing outsized interest from investors who see a clear and pressing need to bring farming into the future. Investment in agriculture-related technology reached USD 16.9bn last year, up 43% from 2017. Even luminaries like Jeff Bezos and Bill Gates are getting in on the game, investing and pushing sustainability solutions without compromise.

It's been frequently observed that improvements in computing power have largely kept pace with Moore's Law, the observation that says the number of transistors on a chip roughly doubles yearly as costs halve. The plummeting cost of advanced technologies means that the world around us is becoming more connected. According to the WEF, there were just 500 million devices linked to the Internet in 2005; today there are 8 billion. By 2030, the estimate is for 1 trillion. In fact, no sooner had the so-called Third Platform technologies (mobile, cloud, big data/analytics, and social technologies) become part of our landscape than the innovation accelerators, or Fourth Platform – i.e., machine learning, IoT, robotics, 3D printing, next-generation security and personalization ¬– arrived.

In the rapidly scaling digital marketplace, they have become the key growth drivers for many companies. Tech has become so ubiquitous in our lives that it has redefined the meaning of everyday English. "Cloud" now refers to computing delivered through a network; "tablet" refers to a smart device used to browse; and "stream" refers to playing videos on the internet. Nevertheless, the speed of innovation led the WEF to declare 2016 the start of the Fourth Industrial Revolution, one based on the concept of merging of physical, digital, and biological technologies – or in food production, "Farming 4.0." What's more, it's become clear that the impact of diffused innovation and the wide application of digital technologies are more fundamental and transformational in nature than we could have envisaged. The value of data grows in relevance as it becomes easier to create and collect data.

Source: Getty Images

What's needed now is a platform that unifies these disparate technologies into something intuitive and affordable for average farmers. They will also have to secure the talent necessary to unlocking the insights hidden in their data. Knowledge-intensive food production tools like environment sensors, mobile computing, satellites and imaging, drones, wireless communication, and even genetics will require that data-savvy talent be attracted to the sector. Also, labor-saving techniques, like robotics, might reduce employment for traditional jobs, making it crucial that the industry has a game plan for coping with the side effects of automation.

Food for thought

As recently as 2018 food production ranked dead last in terms of adopting digital technologies – digital penetration in agriculture is 0.3%, versus 2.5% for financials and close to 12% for retail.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

No.9: Industry, innovation and infrastructure. FAO promotes sustainable development in rural communities through investments in transportation, storage, irrigation and communication technologies.

Trend 5: Sustainable living

Several converging trends have moved food and agriculture up the sustainable living agenda. Governments all over the world are increasingly paying more attention to the United Nations' 17 Sustainable Development Goals (SDGs) and the Paris Climate Change accord. This clearly indicates an emerging awareness that societies need to transition to a low-carbon economy, which will require all individuals to become more efficient in their energy and water use, as well as waste less.

Regenerative agriculture, for example, has the potential to sequester carbon dioxide from the atmosphere and store it. This not only halts the industry's impact on the environment but also reverses it. As a larger population with emerging wealth fuels the demand for consumer products, nature's limits will become ever more apparent. Overall, the global community needs to focus on working collectively towards a circular economy with food at its center.

An inclusive food production system that doesn't leave behind small landholders, women and youth, minimizes its environmental footprint, conserves natural re- sources, and strengthens communities against supply-side shocks is another goal. We have no doubt the impact of a changing climate and the constraints of resource scarcity will significantly influence policy-makers' decisions in the coming years as inhabitants pressure city municipalities to clean the air, and food producers to reduce GHG emissions, rebuild biodiversity, and reduce waste. Likewise, impact rather than profit will become a core value of food companies. Many innovative companies are plotting new technologies to improve the efficiency of food production.

According to the WEF, profit with purpose is set to become the norm. Unilever is a good example of how major conglomerates might soon be developing a purpose-led strategy for their core business. Its outgoing CEO, Paul Polman, has been among the first business leaders to give a new, more profound meaning to the word "sustainability." He regards it not just as the right thing to do, but an essential component of growth.

We are seeing many companies already going beyond compliance. According to KPMG, nearly 90% of the world's biggest companies are reporting on their sustainability performance using metrics established by the Global Reporting Initiative (GRI), established in October 2016. Although governments' engagement has been uneven, they are seeking policy interventions to green the food industry as well.

Let's look more closely now at the great challenges of waste, a changing climate and water access in the coming pages.

Source: C.J. Wadhwa

11 SUSTAINABLE CITIES AND COMMUNITIES

No.11: Sustainable cities and communities. By 2030, two-thirds of the global population will be urban dwellers, and by 2030 Asia will have nearly half of the world's urban residents. Rapid urban growth is placing enormous demands on food systems.

13 CLIMATE ACTION

No.13: Climate Action. Food production threatens to be the greatest casualty of climate change, but sustainable agriculture can be part of the solution. Food production accounts for around 30% of human-generated greenhouse gases.

14 LIFE BELOW WATER

No.14: Life below water. Fish accounts for 17% of the world's intake of animal protein. According to the FAO, over 30% of the world's fish stocks are currently being overfished.

15 LIFE ON LAND

No.15: Life on the land. Agriculture is the most significant drivers of deforestation (roughly 80%) and biodiversity loss. According to the FAO, 25% of all farmland is already degraded, with different aspects of food production contributing to this process.

17 PARTNERSHIPS FOR THE GOALS

No.17: Partnerships for the goals. It will take a coalition that includes traditional and non-traditional investors, entrepreneurs, growers, and governments to meet the challenges ahead. According to the Business and Sustainable Development Coalition (2016), these opportunities could be worth USD 2.3 trillion annually by 2030.

Waste is everyone's business

Source: Nikolai Chernichenko, Unsplash

Waste minimization is a global challenge. The UN estimates 1.3 billion tons of food is lost or wasted annually, equating to roughly one-third of global food production. Such extreme waste comes at a significant financial and environmental cost. Food is wasted in almost every category: 45% of fruit and vegetables, 30% of cereal products, 35% of fish and seafood, 20% of dairy and 20% of meat. The World Resources Institute estimates this amount accounts for 8% of GHG emissions. If waste were a country, it would be the third-largest GHG emitter. Food waste occurs at every step in the value chain – but it is most pronounced at the beginning (production) and at the end (consumption).

In developing countries, the problem is largely a function of the production and transportation of food from farms. In developed countries, it is most prevalent in the consumption phase, among both retailers and consumers. For example, China produces up to 18m tons of food waste every year – enough to feed up to 15 million people and worth an estimated USD 32bn (UBS, 2019).

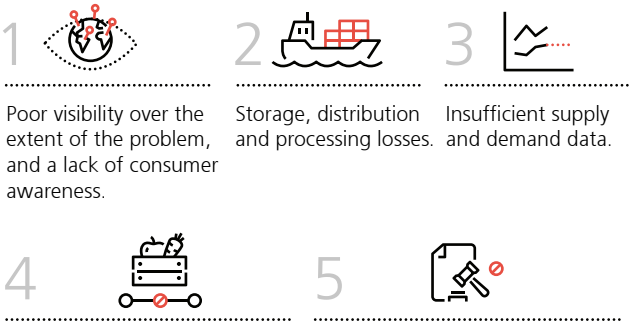
In food production, this translates not only into greater use of renewable energy on farms, high-tech animal feed, and processing facilities but also includes soil health management. Historically, innovations like precision agriculture were developed by businesses purely for commercial reasons. But this time we can expect to see significant growth in the scale and impact of social enterprises on all aspects of daily life, fueled by entrepreneurs with a desire to not just make money but to also make a difference by investing for good.

Waste is everybody's business

% of food wasted across the value chain

Source: United Nations

Five key drivers of food waste

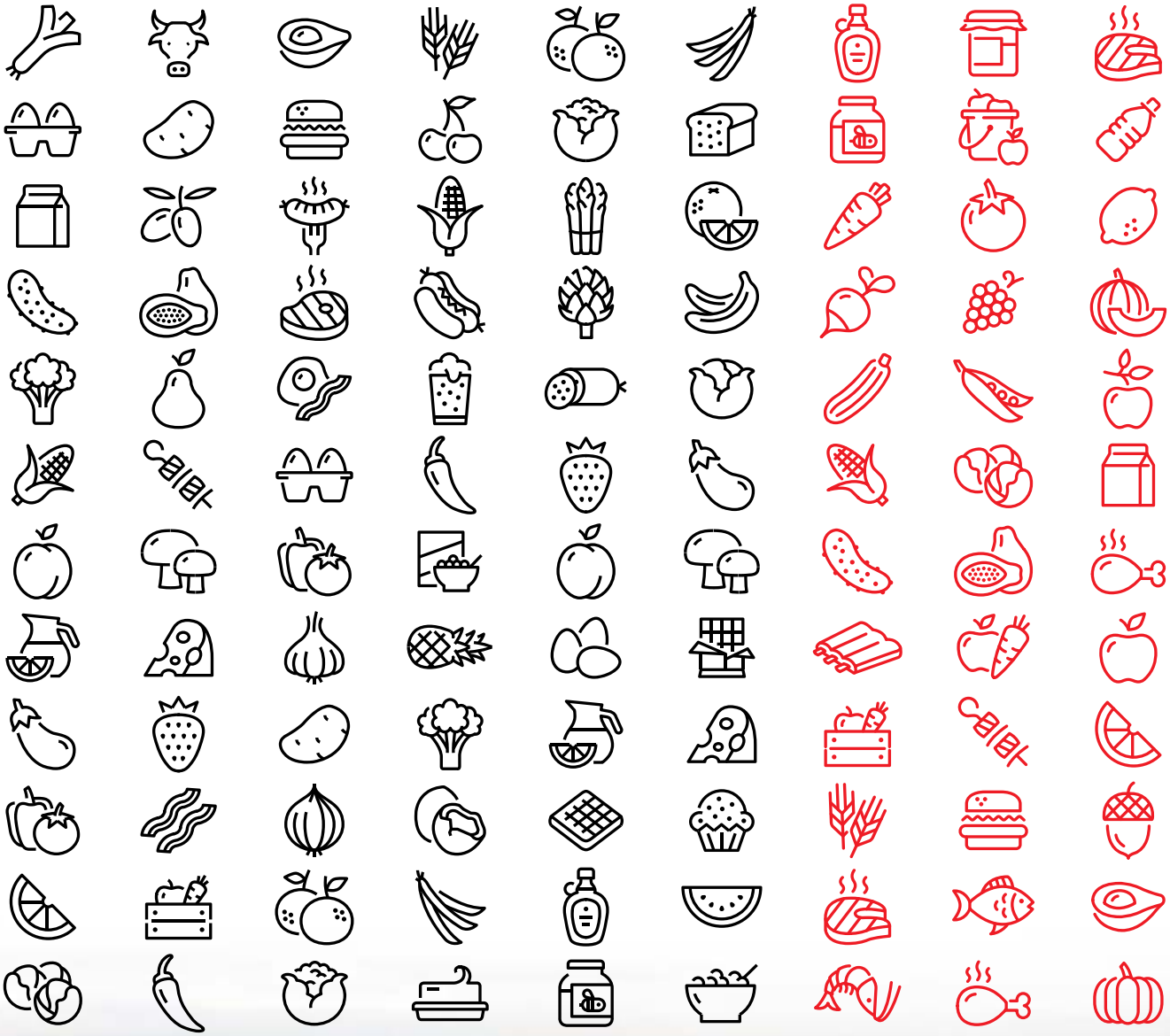


Source: Boston Consulting Group (2018)

1/3 or 1.3 billion tons

of global food production is lost or wasted annually

Annual global food production



Source: United Nations

This interview contains views which originate from outside Chief Investment Office Global Wealth Management (CIO GWM). It is therefore possible that the interview does not fully reflect the views of CIO GWM.

Marc Zornes
Marc Zornes is a former McKinsey Engagement Manager where he was a leader in the consumer & sustainability practices.

He founded Winnow to help the hospitality sector cut food waste using technology. Winnow builds tech to help chefs run their kitchens more efficiently focusing on helping them understand and prevent food waste.

Since launch five years ago, Winnow has been deployed in 40 countries and has saved its customers USD 33m by reducing food waste. The company claims that kitchens using Winnow typically see food waste cut in half within 12 months, and chefs using Winnow are collectively saving 23m meals a year from the bin.

Marc is one of UBS's Global visionaries. Visit www.ubs.com/globalvisionaries to know more.

Interview with Marc Zornes

How much of a problem is food waste?
There is significant progress in pushing energy towards a lower carbon future. Now, the food system is coming into focus as an area where society needs to make significant change. In fact, one third of all human-caused greenhouse gas emissions come from our food system. One major contributor of the environmental impact of the food system is food loss and food waste.

Food loss and food waste is a major economic and environmental issue. Globally, ~30% of all food is wasted from farm to fork. From an economic perspective, this waste is a material global economic cost. BCG recently cited that USD 1.2 trillion a year is wasted and will grow to USD 1.5 trillion a year by 2030. To put that into perspective, that's 1.5% of global GDP. From an environmental perspective, addressing food waste is a one of the top issues as well. If food waste were a country, it would be the third largest emitter of greenhouse gasses after the US and China. Project Drawdown, a global study of actions we can take to reduce climate change, highlighted food waste as one of its top three opportunities.

In the developed world, food waste occurs mostly at farms, homes, and consumer-facing businesses. In the US, ReFed estimates that these three areas contribute to >90% of all food wasted. There are many businesses set to address food waste across each of these points in the supply chain.

Where is progress most evident? Setbacks?
Governments are beginning to make a material effort in reducing food waste and food loss. The UN put halving food waste into the Sustainable Development Goals for 2030. As a result, the EU, US, and many organizations have put targets to halve their food waste by 2030 or even earlier.

In France, for instance, it is illegal for supermarkets to throw away edible food. In the US, ReFED is building action plans across key points in the food supply chain to reduce food waste. The UAE's Ministry of Climate Change has set an ambition to prevent 3m meals a year from being wasted in the hospitality industry by 2020.

These movements are exciting. Yet, they are only the beginning of the change we need to see. It's clear that reducing food waste is not a simple ask. That said, with an opportunity >USD 1 trillion p.a. to go after, there is a growing amount of capital pouring in to find and scale solutions that are working.

What emerging technologies look most impactful for reducing food waste?
There are many exciting technologies that are out there to reduce food waste. The number of companies aimed at reducing food waste has grown from a handful to thousands globally in less than a decade. Most companies fall into three main categories: Food waste prevention, redistribution, and valorization.

Food waste prevention has the biggest economic benefits as it saves the cost of the food being wasted. My business, Winnow, is focused on preventing the USD 100bn of food waste in the hospitality industry. Winnow saves clients 2% to 8% of their food spend where it applied. We work with major global food operators including

This interview contains views which originate from outside Chief Investment Office Global Wealth Management (CIO GWM). It is therefore possible that the interview does not fully reflect the views of CIO GWM.

IKEA, Compass Group, Accor Hotels, IHG, and Carnival Cruise Lines. Apeel Sciences is another exciting example. Apeel Sciences produces plant-derived protection on the surface of fresh produce to extend its shelf life.

Redistribution-focused businesses are beginning to scale as well. Too Good to Go and Karma are creating secondary markets to sell food that would otherwise be wasted. FoodCloud is doing a similar program for the retail sector. Olio is an app that allows peer-to-peer food sharing with a similar angle but with more emphasis on the home.

Valorization is the technology to create more value out of food that would be wasted. Treasure8 preserves food that would be wasted to create whole-food inputs into the consumer good sector. Toast Ale is a beer made from bread that would be wasted.

The above companies are not an exclusive list. Remember, it's a USD 1.2trn problem that is growing. It's clear that there will be a massive set of solutions out there needed to capture the opportunity of minimising food waste around the world.

What has AI taught you about the problem, and solutions?
Andrew Ng, one of the global thought leaders on AI, describes deep learning and artificial intelligence as "the new electricity". AI is a powerful tool to allow us to do things that have previously not been possible. We apply deep learning in the field of computer vision. Our latest technology, Winnow Vision, uses a camera to identify the food that's being wasted, making it seamless in collecting food waste data. This innovation dramatically reduces the adoption costs of food waste monitoring and prevention. It also increases the potential this technology can have on impacting the problem.

We have plans to go well beyond the identification of food waste via AI. We're exploring how we can apply AI to analyze consumption patterns in kitchens and improve overall how the kitchen operates. While many companies are looking at robotic automation in the kitchen, we focus on how AI can improve the efficiency of the kitchen staff. We aim to drive massive performance improvements in an environment which have historically applied little digital innovation.

How can investors benefit from better food waste prevention and efficiency?
If you own or operate an asset that has a foodservice offer, the benefits of food waste prevention will be direct to the bottom line. In addition, as you reduce waste, you also are better managing production relative to customer demand. This has the benefit of improving customer satisfaction.

If you have an appetite to invest in emerging technology to solve this problem, then there is a broad spectrum of opportunities out there. There will be multiple billion-dollar companies built focused on addressing the issue of food waste. The economic case is clear, most opportunities have a payback of less than 1 year. Both governments and non-government are creating additional tailwinds to grow these markets. The question will be how quickly large corporates will adopt the technology. Then, who of the thousands of organizations trying to solve the problem will reach the scale to drive meaningful change?

A changing climate

Source: Getty Images

Changing weather conditions will have a major impact and constitute the chief challenge the food supply chain needs to address. Their effect on soil and produce quality and the second-order effects on the natural system are likely to be considerable.

More corporations are placing a greater emphasis on environmental considerations when setting their strategies related to food production and the wider supply chain. This heightened importance is reflected in the rapid adoption of reporting on environmental, social, and governance (ESG) matters, where targets are being set, published, and monitored. At the institutional level good environmental practice is forming an increasingly integral part of farm policy. For example, farm subsidies in the EU are being made conditional more and more on good agricultural practice.

The impact of global warming on food production is the subject of much research and debate. Assessing the timing and impact of global warming on agriculture is still very much a developing field. Current conventional wisdom (according to the UN) is that crop production will move toward the earth's poles and the greatest negative impacts from climate change will be felt by countries and populations closest to the equator. The Brazilian state of Mato Grosso, one of the most important agricultural regions worldwide, might face climate-related changes that reduce soybean and corn output by 18% to 23% by 2050, according to the UN. The Midwest US and Eastern Australia – two other globally important regions – might also experience a substantial decline in agricultural output due to extreme heat (note: the US and Brazil are the biggest producers of soybeans, and 80% of these soybeans goes to feeding animals).

Paradoxically, there are yield benefits (in the short run) to higher concentrations of CO2 and potential productivity gains at higher latitudes – mainly in China, Canada, and Russia, certain areas of which are expected to experience longer and warmer growing seasons, although soils tend to be poorer there.

Water access our greatest challenge

Source: Getty Images

Rising global temperatures could increase water scarcity. And, as discussed earlier, scientists warn that the climate may become less predictable, which could strain the water supply and worsen the water quality in aquifers and streams, compounding the challenge.

Water use has tripled since the 1950s and demand continues to soar. By 2030, the world may face a 40% water supply-demand gap. This could double to 80% if wastewater isn't treated properly. World Bank research shows climate-driven changes in water runoff will have uneven effects around the world, with those areas already suffering from water shortages likely to be hit hardest. Reduced runoff increases demand for groundwater, especially for irrigation, which is responsible for 70% of global groundwater withdrawals (WWAP, 2012).

Less talked about, but equally as devastating, is the decline in water tables and aquifer water quality. As a consequence, groundwater salinity will rise due to higher temperatures and rising sea levels. This could culminate not just in reduced supply and lower yields but poorer food quality and consumer health. The least developed countries, where water-consuming activities such as agriculture and energy generation are particularly important, are likely to suffer most.

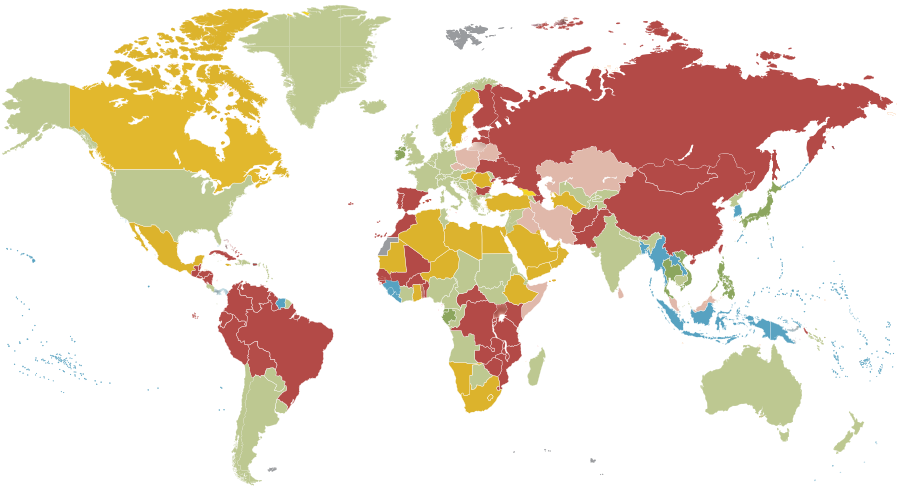
Food for thought

By 2030, the world may face a 40% water supply-demand gap.

Indeed, the lack of clarity about how the climate is evolving is increasing uncertainty about how to manage water, adding to the risk that countries' investments might prove insufficient and/or ineffective.

Climate-driven drops in runoff* hit least-developed, agriculture-dependent countries most

Projected fall in millimeter per square meter by 2050



- Below –200
- –200 to –100
- –100 to 0
- 0 to 100
- 100 to 200
- Above 200
- No data

*** Definition of runoff**
Part of water cycle that flows over land as surface water instead of being absorbed into groundwater. This is a key and easily accessible water source for man, animals and particularly the agricultural sector in the least-developed regions worldwide

Source: World Bank (High and dry: Climate change, water, and the economy) as of 2016

Chapter 3

Tech unseats tradition

Busting the myth that technology is the enemy of natural, abundant and affordable food.

Shipping container with installed aquaponics system in Czech Republic.

Source: Getty Images

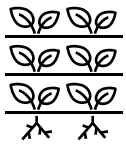
Ready-to-go shipping container with installed aquaponics, system combines fish aquaculture with hydroponics, cultivating plants in water under artificial lighting.

In contrast to stereotypical images of Western farming, most farms globally are small, with 72% less than one hectare and only 6% exceeding five hectares (UN, 2016). Most are operated by a family largely to provide food for subsistence and use minimal, primitive technologies.

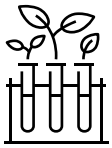
Conventional wisdom has been that more food is produced by increasing scale, consolidating family farms into broad-acre farms or large-scale pastoral operations, or by utilizing feedlots, or by housing animals in sheds. These intensive systems, which differ greatly from our image of a pastoral idyll, have raised consumer concerns about the impact on the environment and water quality; on the welfare of animals; and on the nutritional quality of the food being produced.

These worries arise even before we consider the impact these systems have on rural communities, the risks of consolidating production in a single area, or the environmental footprint associated with distributing the product. As a consequence, the search is on for new farming models that focus on meeting the nutritional needs of the population while better utilizing natural resources and embedding food production closer to those who will ultimately eat the food.

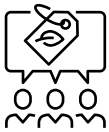
While predictions are useful, we are still a long way from 2050, and a whole new generation of growers will be farming by midcentury. Much will happen between now and then that we cannot predict, but if the past is any guide, there will be widespread adoption of precision technology, which will be truly automated and factory-like with robots on the ground as well as in the air.



Urban/Vertical farming



Lab-grown food



Organic food becomes mainstream

Algae acquaculture a game center

Source: Getty Images

Farming turns urban and vertical

Urban farming and vertical farming are among the innovative solutions starting to gain traction around the world. They can take the form of commercial production in sky farms on top of offices or supermarkets, communal allotment areas (located on grass verges due to lack of space), edible borders in parks and gardens, living walls on buildings, and social food projects set up to support disadvantaged communities.

Core to these technologies is innovation in the use of lighting systems that enable plants to grow quickly and with enhanced nutritional properties. Vertical farming is especially valuable in urban areas where land is scarce and expensive. The range of crops that can be economically grown in these systems is increasing, while the costs associated with developing a facility are decreasing – making them more and more commonplace in many cities around the world. For example, Crop One Holding in June 2018 partnered with Emirates Flight Catering to create the world's largest vertical farm – 130 thousand square feet – which is due to open in Dubai by the end of 2019.

Overall, the concept appears to us to check several waste-mitigation boxes, amounting to substantial environmental benefits versus traditional agriculture. These include:

- 95–99% less water required versus conventional field grown produce, no agricultural runoff (we were told waste water is potable);
- Considerably less acreage required (the farms are stacked vertically within pods in industrial buildings);
- Zero use of pesticides, herbicides or fungicides (sealed environment with no soil), and less fertilizer use (plants are "micro-dosed" with no excess or wasted fertilizer).

Energy use, and specifically its carbon footprint, is regularly cited by those who oppose vertical farming - roughly 70% of the cost of goods sold is linked to electricity use. But our understanding is that advances in LED technology are expected to continue to reduce costs in the coming years. Moreover, these costs must be considered alongside the benefits of people eating as "local" as possible: Less food miles (the distance fresh-grown produce is transported) equals urban populations getting the freshest food possible, which encourages us to eat in season and reduces the overuse of harmful packaging.

Source: Getty Images

Scientists move into the meat business

The ability to create food that replicates meat, fish, eggs and dairy products – with a lower carbon footprint and without the need to slaughter animals – is likely to become a commercially viable option in the next decade. For example, growing meat in a lab could cut GHG emissions caused by agriculture by 78–96% while using 99% less land, according to the journal Environmental Science & Technology (2011).

And lab-grown or "cultured meat" could be a bridge between real meat and plant-based products. Netherlands-based Mosa Meat uses self-reproducing cells to produce meat that is an "animal-based" product while avoiding the need to breed, raise, and slaughter huge numbers of animals. Scientists take stem cells from an animal – cow, pig, chicken, and sea creatures – and place them in a growing medium in a bioreactor to produce "cultured meat."

While science can't yet create the texture of a fine steak, processed meat such as burgers, chicken nuggets, and meatballs are getting good reviews and are expected to be available on supermarket shelves within five years. Other companies like Singapore's Shiok Meats are focusing on cell-based seafood where scientists replicate shrimp stem cells in a lab to create edible tissue. Ultimately, the idea is for these cells to be cultivated until they grow large sheets of whole muscle tissue. This vision is not yet reality, with several firms highlighting technical challenges replicating the texture and shape of real meat.

Also, for now, price is the barrier; in the US, ground beef that comes from livestock in the country costs around USD 5/pound (USDA, June 2019) while the price is roughly USD 100/pound for lab-grown beef (versus Beyond Burger at USD 12/pound; June 2019, Washington Post). This gap will undoubtedly close as private investment and demand increase; in March 2017, Memphis Meats told the Wall Street Journal that it had gotten the price of a pound of cell-cultured chicken down to USD 9,000/pound, and just a year later its CEO announced the price had dropped to below USD 1,000/pound (Washington Post, 2019).

The other battle over these new meat alternatives, aimed at preventing companies from using the term "meat" for anything other than conventionally raised meat, has already turned political, with legislation being proposed or has already been passed in a number of jurisdictions. Still, big corporations involved in the meat industry are themselves also investing heavily in meat innovation as a form of outsourced R&D; an example is Swiss meat-processing giant Bell Food Group, which has invested in Mosa Meat.

Source: Getty Images

Organics enter the mainstream

The local food movement has become a notable component of the premium food sector that has emerged around the world in recent years. It was born of the desire to assess the integrity of the person who grows your food and regards this process as integral to ensuring healthier, safer, more environmentally sustainable food.

Small farmers' markets sprouting up in urban areas constitute a separate movement in itself, but organics are seen as part and parcel of this broader trend. Nevertheless, organic farming tends to polarize thinking. One camp argues that widespread adoption of organic practices will starve half the world, while the other sees it as crucial to healthier eating. The key question is whether organic produce represents a necessity or it is just a desirable option for consumers.

As we understand more about the toxins and carcinogens that permeate our daily lives, the commitment of many consumers to organic and biological products appears to be building.

Concerns that high-value customers have about the safety and nutritional quality of their food as well as about innovations in how products are branded and marketed to consumers are creating a less elastic demand profile for these products. One main argument against organics is the lower yields achieved with them. This issue appears less relevant in the context of the organic sector as it is increasingly benefiting from the same digital and precision technologies as non-organic farmers. Another worry, as we mentioned in Trend 3, is that consumers who select only organic produce would miss out on many of the benefits of the new generation of innovation by seed scientists.

Food for thought

The key question is whether organic produce represents a necessity to or a desirable option for consumers.

Source: Getty Images

Microalgae could alter the world

According to the FAO (2016), 50% of the seafood consumed each year comes from aquaculture. What's more, it predicts the aquaculture industry will continue to boom – production is seen increasing by 34% by 2026. In the midst of everything, this has put enormous pressure on feed supplies, which are mostly made up of forage fish, soy and other grains. In fact, about 90% of the 20 million tons of forage fish pulled from the wild each year are ground into meal or oil to nurture fish farmed for human consumption (Tim Cashion, Frédéric Le Manach, Dirk Zeller, Daniel Pauly, 2017).

This problem has spurred researchers to try to manufacture a stand-in that will provide the nutrients found in forage fish, be economically viable, yet not deplete resources such as grains that humans directly depend on for food. Algae could be a viable replacement fish fatty acid source for this species of farmed fish. Industry research reveals that algae grows as much as 10 times faster than terrestrial plants, and less than one-tenth of the land is needed to produce an equivalent amount of biomass.

However, scaling up presents the biggest hurdle as replacing the 22 million tons of wild aquaculture fish used every year will require massive volumes of microalgae production. Production costs would also be required to drop, as farmers will otherwise opt for the adequate and cheaper grain. According to an article by Leslie Nemo in the Scientific American (2019), other inherent hurdles to ramping up production are nailing the right ratios of fatty acids, such as omega-3s, and simulating the natural balance found in fish oil.

Researchers must either find the perfect algal or yeast strains and feed them the right starter, so associated microbes produce everything in proportion—or they must combine fatty acids from various sources, which makes coordinating production even more difficult. As well, questions remain about how much greenhouse gas the imitation feed refinery processes will emit.

In our opinion, the overcoming of these hurdles will be crucial to meeting human needs without adding to the mounting pressures on marine ecosystems from overfishing and climate change.

Chapter 4

Embracing innovation at the farm

Challenging the fundamentals of how, where, and which food we grow.

Farm field in Bulgaria

Source: Getty Images

Farmer flying drone over farm field.

We appear to be on the cusp of a major step change, not only in productivity, but in challenging the very fundamentals of how, where, and when we grow food. Start-ups and corporations have a range of technological innovations that, by integrating digital solutions into farming systems, increase the precision application of nutrients and other inputs – i.e., "Farming 4.0." They do so while minimizing damage to soil, taking advantage of unmanned vehicle advances both on land and in the air, and enhancing animal and plant genetics, nutrition, and health to improve productivity.

The magnitude of the opportunity is best illustrated by the increase in investment in these technologies over the last decade. In 2008, agritech investments amounted to an estimated USD 100m. This figure rose to USD 4.2bn by 2018, according to KPMG (2019). Data-driven agriculture is already helping farmers and food producers discover innovative ways to grow more with less. As urbanization reduces the rural labor force, new technologies will be vital in easing the workload on the remaining farmers. Operations will be done remotely, processes will be automated, risks will be identified by machine, and issues will be resolved by keying orders into a central command center. In the future, a farmer's skillset will increasingly be a mix of technology and biology abilities rather than pure agricultural knowhow.

The good news is that farmers are already comfortable with technology. Yet, according Adrian Percy (2018) a disconnect remains. He believes that until we find a value proposition for farmers to get involved in agritech, they will (rightly) remain largely skeptical of the new products. The onus is on technology to prove digital advances aren't just eco-friendly bells and whistles. They need to make it possible to produce more, higher-quality food with less manpower. And entrepreneurs bringing those products to market will need to actively gather feedback from the users they're trying to help.

Poor connectivity and the lack of integrated practical solutions are other reasons digitization has lagged. Also, robotic machinery remains prohibitively expensive and point solutions like drones and IoT-enabled fields are costly and come with a steep learning curve.

We're not quite there yet, but the landscape is changing and better options are emerging (we discuss examples on the following pages).

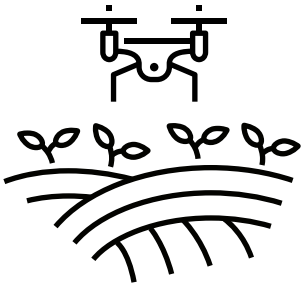
Robots on the ground…

Tractor guidance and auto-steer are well-established technologies; but unmanned autonomous tractors will take longer to become conventional. Regulation, high sensor costs, and the lack of farmers' trust are the limiting factors, not the technology itself. The rise of smart implements, however, is gathering pace. Indeed, advanced vision technology has been enabled by machine learning (i.e., deep learning). Here, machines learn to distinguish between crops and weeds as the implement is pulled along the field, enabling them to take site-specific weeding or spraying action. We anticipate that such implements will become increasingly common. They are still in their early infancy and the software is still being worked on. A joint venture between Bosch and Bayer to develop intelligent sprayers is nearing major commercialization.

Outside of broad-acre agriculture, the application of agbots has been limited; in horticulture, particularly, smart technology has been largely confined to irrigation. But a few fresh-strawberry harvesters have been trialed and some are transitioning into commercial mode. The task remains technically challenging though: the vision system needs to detect fruits inside a complex canopy while robotic arms must rapidly, cheaply, and gently pick the fruit. Novel end-effectors, including those based on soft robotics that passively adapt to the fruit's shape, have improved grasping algorithms underpinned by AI learning processes. Low-cost, good-enough robotic arms are working in parallel, and better vision systems are all helping push this technology toward commercial viability.

In dairy, thousands of robotic milking machines have already been installed world-wide. For example, there are 3,959 automated milking systems in the Netherlands, of the total of 17,667 milking installations (Dairy Global, 2018). This means that roughly 22% of Dutch farmers have a robot, and the industry will continue to expand as their viability is established.

Source: Getty Images



...and drones in the air

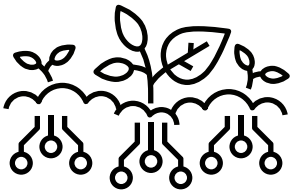
Drones are now being used at every stage of the growing cycle. They produce precise 3D maps for early-soil analysis, assist in the planning of seed planting, and gather data to help manage irrigation and nitrogen levels.

Agriculture is emerging as one of the main addressable markets for drones as the industry pivots away from consumer models that have become commoditized in recent years. New start-ups have created drone-based planting systems that de- crease overall planting costs. These systems shoot pods with seeds and nutrients into the soil, providing everything needed for crops to grow. Also, in the application of crop-protection chemicals, drones can scan the ground for potential issues (e.g., pests, fungal breakouts, etc.). In fact, aerial spraying can be five times faster with drones than with traditional machinery.

Inefficient crop monitoring is a huge obstacle to higher production. With drones, time-series animations can show the development of a crop and reveal production inefficiencies, enabling better management. By scanning a crop using both visible and near-infrared light, drone-carried devices can help track changes in plants, and analyze their health and alert farmers to disease.

Source: Getty Images

Big data and connectivity



In our Long Term Investment theme "Enabling technologies," we identify cloud and big data as two of the five enabling technologies set to empower technological disruption across many industries and potentially even displace incumbent industry leaders. The rise of cloud technology is a democratizing IT, in our view. It enables smaller businesses to use enterprise-class applications, while big data can help extract significant value from large and untapped pools of data too complex to manipulate with standard methods and tools.

In food production, connected devices like IoT and sensors make it possible to gather vast amounts of data for analysis by cloud and big data technologies. The result is in-depth knowledge of agricultural factors, such as humidity, local rainfall rates, and temperature variations, which can be used to optimize many processes.

In South America, for instance, the FAO ran a project on water efficiency using IoT devices, cloud storage, and big data technologies. After analyzing the data, the body made practical recommendations to help farmers make better decisions. Likewise, Cargill has taken a stake in Cainthus, an Irish startup that uses facial recognition software to identify individual cows and track herd health aimed at increasing productivity in dairy farms.

The IoT has been constrained by inadequate access to connectivity, especially in rural areas. Investment in communication networks in the outlying areas of many countries and the transformational potential of 5G technologies and other low-powered network solutions are making digitalization of the sector more feasible for many remote rural producers. As the economic and social potential of high-speed broadband is recognized, such rural connectivity is increasing. And resistance to change is falling as the industry not only enters a period of generational succession but the financial and environmental benefits of digitally augmented farming become more apparent. The shortage of solutions diminishes as demand grows.

IoT is one of the fastest-growing technology device markets (units in bn)

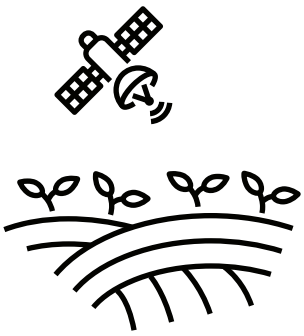
IoT	2018	2024	CAGR
Wide-area IoT	1.1	4.5	27%
Short-range IoT	7.5	17.8	15%
Total	**8.6**	**22.3**	**17%**

Sources: Ericsson, UBS, as of November 2018

Source: Getty Images

Food for thought

In food production, connected devices like IoT and sensors make it possible to gather vast amounts of data for analysis by cloud and big data technologies.

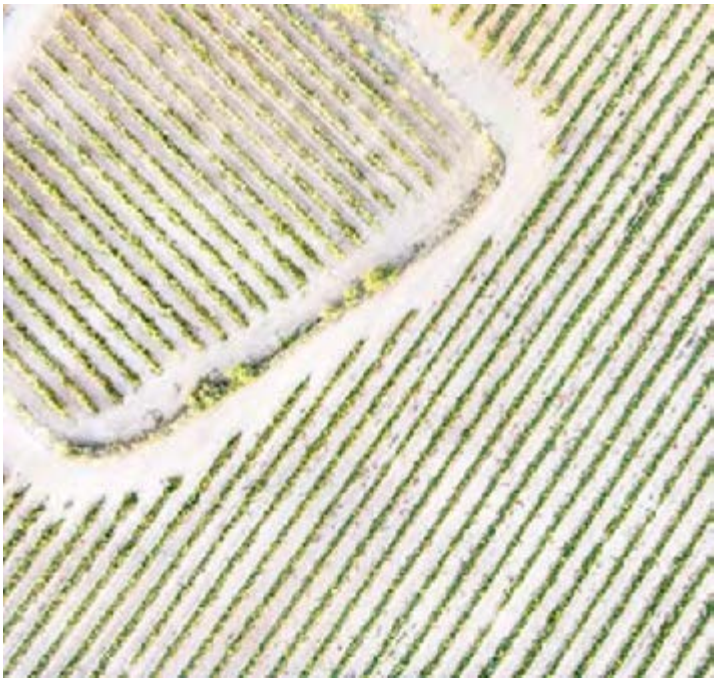


Satellite-enabled systems

According to KPMG (2019), precision agriculture that utilizes satellite-enabled farming is becoming more available as the cost drops and the capability rises to regularly collect large-scale images of land areas from small, relatively low-cost orbiting satellite systems. These images are analyzed with biological algorithms and other tools to observe, measure, understand, and respond to inter- and intra- field variability in crops.

According to the WEF, rapid growth in the application of precision farming technologies is occurring. By enabling the precise quantification of an input (water, fertilizer, or crop-protection chemical) to be applied to specific areas, farmers can simultaneously reduce costs and enhance production yields. Data from various sources – including high-resolution satellite imagery, meteorological records, soil nutrient sensors, water flow gauges, and production reports – can be integrated and analyzed by algorithms to produce highly specific recommendations that not only raise production but take account of the environment.

The most significant benefits will be gained by integrating different types of technology. Big data, IoT, and satellites working in conjunction with sensors will be a game changer when applied across production systems – whether pastoral, horticultural, or any other form of biological production – in maximizing the production potential of land while minimizing the environmental impact on it. Delivering what is possible relies on recruiting skilled people, combing data to derive insights that can improve outcomes, and building the algorithms able to augment the intuition of those operating the system.

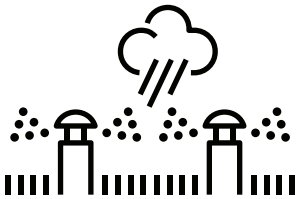


Source: Getty Images

Food for thought

By enabling the precise quantification of an input (water, fertilizer, or crop-protection chemical) to be applied to specific areas, farmers can simultaneously reduce costs and enhance production yields.

Water-saving technology is vital



According to the UN, 2.3 billion people do not have access to adequate sanitation. More than 650 million have no access to safe drinking water. The global food production system is the largest water user worldwide. It consumes 70% of the planet's fresh water. Water scarcity not only affects social and economic stability, it also undermines the sustainability of natural environments and ecosystems. UN research suggests that 43 countries are already experiencing severe water shortages, and estimates that half the global population could be living in areas of high water stress by 2030.

One result of urbanization will be higher industrialization and water use, which will place greater pressure on agricultural, freshwater, and coastal aquaculture resources. The International Union for Conservation of Nature estimates that, by 2050, demands for water, energy, and food will rise by 55%, 80%, and 60%, respectively. As a consequence, there is a growing focus on how the food industry uses water and on the production footprint it leaves. Designing systems and deploying digital and analytic technologies that enable producers to understand their water availability and utilizing them with precision are critical.

Fourth Industrial Revolution capabilities can play a major role in mitigating demand across water-intensive industries. In the agriculture sector, for example, companies like Microsoft are demonstrating how precision irrigation techniques can employ smart sensors implemented in crop fields and satellite images to glean information about soil conditions. Drones take images of fields and AI interprets the data to model a heat map of the crop area.

Distributed ledger technologies offer opportunities to further influence the behavior of traders and end-users by enabling peer-to-peer trading of water allocations among users in an open and transparent manner (discussed further in the Supply-chain Innovation chapter).

Source: Getty Images

Food for thought

According to the UN, more than 650 million people have no access to safe drinking water.

Currently

2.3 billion

people without access to sanitation

Source: United Nations, June 2019

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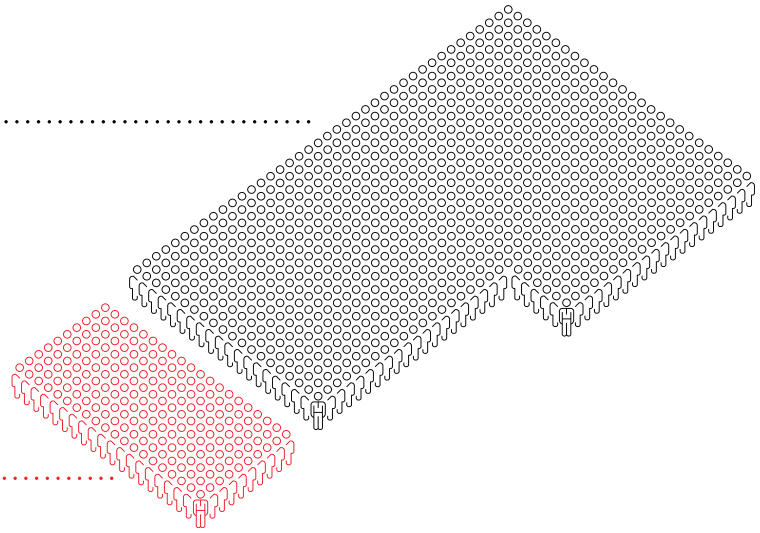

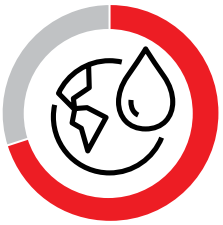

Currently

70%

of the planets's freshwater is used for global food production

Source: United Nations, June 2019

By 2050 global demand will rise:

+55% for water

+80% for energy

+60% for food

Source: The international Union for Conservation of Nature, June 2019

Source: Getty Images

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Adrian Percy
Adrian Percy, who has more than 25 years of experience in the agricultural industry, is an advocate of the need for and benefits of technology in modern agriculture. He currently serves as the CTO of Finistere Ventures, a global technology and life sciences venture capital investor. In addition, he frequently acts as an agricultural industry representative and advisor or independent director to companies through his own consultancy company, Nomad Technology Consulting. Previously, Adrian served as the head of research and development for the Crop Science division of Bayer as part of its executive committee.

Interview with Adrian Percy, PhD

Technology will play an increasing role in food and sustainability initiatives. Its emergence has occurred at a highly opportune time. We face the challenge of an expanding population to feed, fuel, and clothe with increasingly limited resources available to us – whether we're talking about land, soil, water, nutrients, or labor. Also, our changing climate is influencing the natural limitations of the planet.

So we spoke with Adrian Percy, PhD, a luminary in the field of agriculture and food science. We questioned him about how technology can support global food security while conserving the environment.

What kind of investment opportunities are there in agritech?
We need to completely transform our agricultural and food production systems to ensure food security for all, meet evolving consumer demands, and conserve our planet's precious resources for generations to come. There are numerous new exciting technologies that can be applied to raising agricultural productivity, safeguarding environmental health, and satisfying evolving consumer preferences.

For instance, bringing effective new technology to growers to replace, complement, or simply increase the efficiency of existing crop-protection methods offers major opportunities. They include bio-solutions with improved environmental safety and completely new approaches that improve yield and increase natural plant resistance to disease and pests, such as the UV technology being developed by BioLumic.

I am also excited about advanced breeding tools, such as those being developed by Hi Fidelity Genetics. The application of computational breeding approaches can help identify new agronomic and quality traits in a much more precise manner. It speeds up the work of plant breeders and creates more efficient seed varieties that benefit growers and consumers alike. All of these technologies can be applied more effectively and efficiently on the farm through the use of better above- and below-ground sensors, application tools, and enabling digital platforms.

Who will drive this transformation?
This time, in my view, major agri-corporations can't solve all the challenges on their own. It will take a coalition that includes new entrants, growers, and governments to meet the challenges ahead of us.

We need to focus on open innovation and collaboration; I hope and expect to see this sector and ecosystem mature as investment interest in it deepens and diversifies. I think new and exciting technologies will emerge from within agri and as crossovers from other sectors, such as pharma.

The food chain appears to be shortening. Consumer preferences, including a demand for more transparency and traceability in it, will increasingly drive behavior on

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the farm. In fact, one of the most exciting developments is the emergence of agri-tech hubs and food-tech innovation around the world.

Growers will be able to customize their operations to a degree unimaginable even a few years ago. Still, these technologies will not be successful unless they are widely adopted on the farm. The companies that offer them need to intelligently negotiate regulatory requirements, gain market access, and offer a clear return on investment to growers.

So, even though innovation is the only path to sustainable farming, technology alone will not solve the many issues confronting modern agriculture. I've talked often about how the loss of trust among producers and consumers diminishes our ability to cope with evolving pests, limited natural resources, volatile markets, shifting consumer preferences, and a changing climate.

You mention trust. Why do we embrace technological advances in virtually all other fields while expecting farmers to continue employing agrarian practices first used more than a century ago?
Modern agriculture, by any meaningful measure, is an unqualified success. Farmers produce more food on less land and feed more people cost-effectively than ever before. But instead of celebrating the advances that have made this possible, many consumers are fearful of them.

This fear stems partly from what I see as an "innovation disconnect." Many consumers no longer have any association with farms and do not understand the realities of farming. That said, acknowledging this situation is not enough. It's up to us in agriculture to help bridge that disconnect and build trust.

After all, it's impossible to sustain a business without trust. While discussing scientific information with the public may be difficult, it's also important. We can start by listening to consumer concerns and finding common ground on where we all agree. We know consumers care deeply about food safety, biodiversity, water quality, soil health, and environmental sustainability. These same considerations are driving the next generation of agricultural innovations. We must draw a clear connection between these innovations and the direct benefits that they deliver to people within their families and communities.

Finding ways to farm more sustainably and provide safe, abundant, nutritious foods to a rapidly growing world is a challenge that only science can solve. I think it's time that we shared our knowledge, conviction, and passion with anyone who will listen. And even with those who won't. We can start this process by talking plainly and openly.

Chapter 5

What's new on the menu?

Gene-edited veggies, plant-based burgers, 3D food printing, and personalized nutrition.

Source: Ailine Liefeld

As the world's population grows in size and wealth and urbanizes, the food industry will need to continuously re-invent itself. It must deal with the practical implications of climate change, natural resource constraints, growing health concerns and the latest fashion and lifestyle trends. What and how we eat now differs from what and how we ate only a generation ago and will differ from what and how we eat in a decade's time. Technological innovation also shapes demand for food products, from its ingredients and flavors to its function.

Today's food producers and processors will need strategies that help enable them to stay relevant. And while the following technologies and the discussion are general in nature, these are the main buckets at the cutting edge of how and what we will eat in the decade, in our view. However, a word of caution, this transition will be not be always seamless. According to Forbes, there is new research offering a warning to companies looking to sell cultured meat. This new type of protein could end up suffering the same fate as GMOs if producers and proponents aren't able to shift the public narrative.

Back then, news reports on GMOs tended to highlight the scientific or economic aspects over other features like yield benefits to farmers, reduced applications of pesticides or more recently, the enhanced benefits of omega-3 fatty acids. Like plant breeders, producers of plant-based and novel foods will face skepticism as advocates characterize artificial-protein products as un-natural, artificial, or synthetic become more vocal.

Recent worldwide surveys tell us that while most consumers support innovations that help fight global hunger, they are also concerned that science today may be harming people and the planet. Innovators need to be attentive to their concerns and responsive to their needs. That doesn't mean we abandon their ideas, but rather improve the quality of these conversations, and engage now.

Biotechnology: Gene-edited food is the next giant leap

Biotech, including via the use of gene modified organisms (GMOs) and CRISPR gene editing, is a major advancement for food production and security. CRISPR technology in particular could make significant inroads to feeding the current and growing world population. Already we struggle to nourish the current population of seven billion people, and climate change will only create new challenges in coming decades. Ultimately, we need to increase agricultural productivity and prevent the loss of biodiversity simultaneously. As such, science will be called upon to help overcome obstacles and meet global food demand.

CRISPR engineered crops would have built-in resistance to drought, pests, and disease, which means less chemical intervention, leading to better environmental outcomes. Besides, produce could be designed to have greater functional benefits, such as a higher vitamin and mineral content which is beneficial to human health.

R&D costs should also decline. According to Rabobank (2019), each new seed variety involves an average total cost of roughly USD 136 million and depending on the breeding method can take between eight and 10 years to develop. However, the use of new marker-assisted breeding technologies such as CRISPR could reduce the R&D spend and timeline to 3-5 years.

Though, many consumers reacted negatively to previous agricultural applications derived from biotechnology (Shew et al, 2017), namely GMOs and put gene-editing in the same bucket, particularly in the European Union. As argued by Shew and Percy, without increased consumer acceptance – likely achieved by improved methods of education and public engagement – CRISPR agricultural applications may face the same regulations and challenges of traditional GMOs, hampering CRISPR's contribution to sustainable agriculture.

According to Percy (2017), future producers, to grow and protect our food, will need these new and diverse integrated technologies that work in concert with the natural environment coupled with real-time diagnostic information – this includes CRISPR technology. We need to bust the lingering myth that technology is the enemy of natural, abundant, nutritional and affordable food. Advocates of biotechnology believe consumers are not be aware that GM crops have outperformed non-GM for more than 20 years in terms of productivity and added to biodiversity – two of the key sustainability indicators.

Source: Getty Images

Plant-based protein is disrupting meat markets

Suspicion about the ability of plant-based meat substitutes to provide a genuinely like-for-like experience as meat has put off many consumers from switching to these products en masse. Nonetheless, their popularity is growing. A key challenge these products face is replicating the fat balance of meat, although new alternative proteins represent a vast improvement in terms of taste over their predecessors and are becoming established.

Perception will be the key challenge when it comes to alternative protein. Plant-based burgers have recently become a fixture of backyard grilling in many countries. Startups and established meat processors are producing them, targeting consumers who have plant- and meat-based diets alike by increasing options for vegetarians and vegans while enticing carnivores to consume an environmentally friendly product without compromising on taste.

This year the stock price of plant-based unicorn Beyond Meat surged more than fivefold in less than two months after it IPOed on the NASDAQ. The California-based startup is one of several second-wave food producers developing innovative processes to more closely replicate the structure and taste of real meat using only plant-based ingredients.

This decade-long path from obscure to mainstream can be traced in part back to the dairy aisle, where soy-, almond-, and coconut-based milks have claimed spots alongside cow's milk. That "same shelf" strategy helped the US non-dairy milk market grows 60%, to USD 21.bn, in the five years to 2017, according to Mintel. It now claims a 12.6% market share from traditional dairy producers.

Beyond Meat has adopted the same tactic. It requests meat-aisle placement for its burger and sausage replacements instead of relegating them to the specialty vegetarian shelf or freezer. Impossible Foods, another second-wave plant-based meat maker, has spent years striving to naturally replicate the taste, texture, and look of a burger meat patty.

Likewise, the alternative-to-dairy market has seen rapid growth and is being powered by, in part, familiar marketing levers – healthiness, humaneness, and sustainability. Another strategy was to push products through high-end partners. Swedish oat-milk maker "Oatly" turned its US capacity constraints into strength, directing early distribution to high-end espresso bars in New York. Scarcity and the barista halo effect helped establish pent-up consumer demand, and set a price point in line or above that of regular dairy products. Another company, Perfect Day, is applying gene sequencing and 3D printing to create milk without the cow.

Source: Getty Images

That strategy has been echoed in early distribution deals struck by Impossible Foods. Its burgers, which take on a blood-red hue from a fermented yeast process, first debuted in limited quantities at New York's high-end restaurants. It has since expanded to over 5,000 US outlets, according to the firm, including a mass market play via nation-wide distribution in fast food giant Burger King. Both Beyond and Impossible have made inroads into Hong Kong and Singapore, tapping high-end restaurants in the trend-setting Asian world cities. Capacity constraints on production, which both have cited as key spending areas in their latest fund-raising rounds, have led to limited availability.

Not surprisingly, plant-based products have faced pushback and regulatory lobbying from meat and dairy industry. Canada, several US states and the EU are in the process of passing, or looking to pass, legislation that would prevent these alternatives from being called "hamburgers" or "ground beef." Other members of the agricultural sector, however, are more supportive of plant-based protein. For example, Canada's AGT Food and Ingredients, the world's largest manufacturer of pulse ingredients (peas, chickpeas, mung beans, lentils etc.), expects demand for flour and concentrates derived from the grains it produces to skyrocket.

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Michael Greger, MD
A founding member and fellow of the American College of Lifestyle Medicine, Michael Greger, MD, is a physician, best-selling author ("How Not to Die"), and founder of the non-profit, science-based public service NutritionFacts.org. He is a graduate of Cornell University School of Agriculture and Tufts University School of Medicine. There are more than a thousand videos on nearly every aspect of healthy eating freely available at NutritionFacts.org.

Interview with Michael Greger, MD

The marketing of plant-based meat has mostly focused on its advantages over beef and other types of animal meat, be it from the standpoint of animal welfare, sustainability or health. Evidence for the first claim is obvious. The sustainability impact of switching from beef to plant-based meat is clear too, with significant advantages in terms of greenhouse gas (GHG) emissions, land usage and water consumption (see Fig. 1).

But the nutritional value of new highly processed plant-based burgers has persistently been questioned in popular media, leaving many consumers alarmed or cautious. At first glance, a side-by-side analysis of a typical beef burger against these next generation plant-based alternatives suggests something of a nutritional draw. So we spoke with Dr Michael Greger, a long-time advocate of plant-based nutrition, to find out more:

Is plant-based meat unhealthy?
The biggest insight from this comparison (see Fig. 2) is that fast food is not particularly healthy, whether it's meat-based or not. A whole food plant-based option, such as a bean burger, remains the most nutritional. But this new generation of plant-based meat appears to lean a little too heavily on salt, with the Beyond Burger containing about 50% more sodium than a typical beef patty. That's about a quarter of the daily intake limit recommended by the American Heart Association. Some types of plant-based meat have comparable saturated fat content, but the plant-based alternatives clearly outperform in terms of transfat and cholesterol.

Is processed food unhealthy?
The True Health Initiative, a global coalition of world renown experts, has established a consensus view that the healthiest diet is one consisting "mostly of minimally processed, generally plant-based foods." Given the impact heart disease has on our society, the lower levels of saturated fat and the absence of transfat and cholesterol in most plant-based options are welcome. And I would like to add that if plant-based meat successfully redirects public consumption patterns away from beef and other types of meat, that could impact related cancer, diabetes, and stroke risks.

Fig. 1. Environmental impact of switching from beef to plant-based meat

Compared to beef	Impossible Burger	Beyond burger
GHG emissions (kg CO2-eq/kg)	-89%	-89%
Land use (m2/y.kg)	-96%	-92%
Water footprint (liters)	-87%	-99%

Sources: Beyond Meat's Beyond Burger Life Cycle Assessment, September 2012, Food policy, December 2012, LCA Update, 2019, Value of water research report series no. 48, 2010

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What do the nutrition charts not tell us?
The most significant advantage not found on the nutritional charts is food safety. Plant-based food has no issues with intestinal bugs, such as E. coli or Salmonella, as the food never had intestines. There are also larger zoonotic disease risks, such as bird flu, that would be lessened by the switch. The scale and speed of modern animal farming have led to heavy usage of antibiotics critical to human medicine. If demand for meat continues to grow, we could see more rampant usage of antibiotics and more antibiotic-resistant bacteria entering the food chain.

Should I avoid GMO plant-based food?
No. Impossible Foods' most high-profile GMO content is a gene-edited yeast designed to produce "heme." This edit allows for vat-based production, significantly ramping up production efficiency. The US FDA has given this ingredient its "generally approved as safe" label. The other GMO content comes from standard GMO soy, which presents its own downsides, including heavy usage of the herbicide glyphosate. Broadly, if you are focused on sustainability goals, this more effective process represents an environmental gain.

Fig. 2. Nutrition comparison between beef and other plant-based meat patty

Based on (113 g) patty

	Beef	Impossible	Beyond	Black Bean
Saturated fat (g)	8	8	6	1.5
Trans fat (g)	1.5	0	0	0
Cholesterol (mg)	80	0	0	0
Calories (kcal)	240	240	280	270
Sodium (mg)	230	370	390	96
Protein (g)	20	19	20	11
Iron (mg)	2.8	4.2	4.2	3.6
Vitamin B12 (mcg)	3	3	0	0
Fiber (g)	0	3	2	7.3
Potassium (mcg)	345	610	300	420

Sources: Beyond burger product detail, Black bean burger, Burger King nutrient information, Impossible Foods FAQ, Mijn Eetmeter, USDA database, 13317, USDA database, 16015.

3D food printing is (almost) here

While next-generation ingredients, robotic appliances, novel cooking methods, and other technology promise to remake our cuisine, 3D food printing has already made its way into experimental kitchens. NASA-spinoff BeeHex's 3D printer prints pizzas for amusement parks, sporting-event venues, large-scale restaurants, and even government/military canteens. By making pizza ingredients in powder form and dehydrating them, their printer has even made pizzas in space.

But the real value of 3D food printing lies in customization. As people's dietary restrictions have increased, the trend toward personalization in food has already gained traction. 3D food home printing would enable people to exert more control over what they choose to eat and the ingredients included in it, but the challenge is to create foods that taste, feel, and look like what consumers expect. The results are getting better. In more futuristic applications, 3D printers will even support specialized diets based on novel foods and ingredients aligned with your nutritional needs or preferences – ranging from iron deficiency to vegetarianism to gluten-free dieting.

Source: Getty Images

Food for thought

3D food home printing would enable people to exert more control over what they choose to eat and the ingredients included in it.

Personalized nutrition goes digital

As consumers become more intricately aware of how their diets affect their health, they will seek products and services that meet their needs and lifestyle. Nutritional advice is fast evolving from a largely static mass market to real-time personalized solutions. In fact, the separation between medicine and nutrition is blurring as diet is being increasingly targeted to preventing and managing chronic disease. Research is linking intestinal health and microbiome to overall well-being and is translating into commercial opportunities and rapid growth.

According to the CSIRO (2019), the value of personalized medicine worldwide is expected to balloon: health and wellness is forecast to rise 5% y/y from 2018 to 2022. The market opportunity is large, and already large corporations are joining forces, i.e., Nestle and Samsung are collaborating to develop a digital health platform. KPMG and others see these partnerships increasing, particularly with major internet platforms such as Amazon, Alibaba, and JD.com.

The promise of startups like Habit, a nutrition tech company partnering with Amazon Fresh and Fitbit to deliver personalized evidence-based nutrition, stems from advanced predictive analytics, affordable diagnostic kits, and rapid updates in wearable technology and IoT. Using blood test results and real-time data such as blood pressure etc., it provides daily food guides, rankings in each food group, and personalized recipes and menus.

Source: Getty Images

Food for thought

Nutritional advice is fast evolving from a largely static mass market to real-time personalized solutions.

Chapter 6

Supply-chain innovation

Food production has lagged all other industries in terms of digitization, but not anymore.

Source: Getty Images

Supervisor taking inventory of merchanidise in a modern warehouse with sacks containing dry produce such as beans and rice.

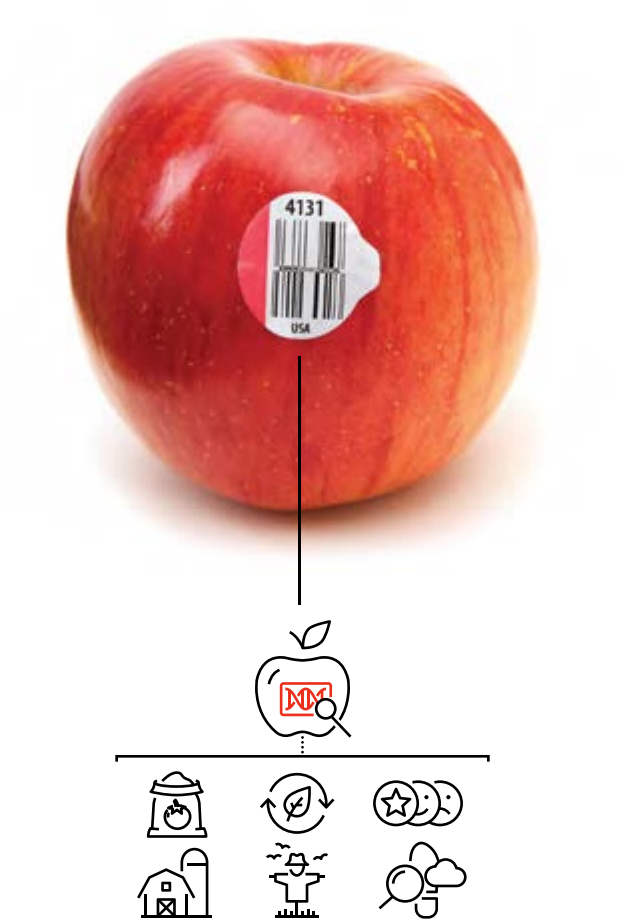
Most consumers are in the dark about how the food they eat gets to the table. Numerous scandals and incidents involving the contamination of food within supply chains have shattered consumer confidence in them and caused considerable financial, political, and health costs. The WHO estimates that almost one in 10 people fall ill every year from eating contaminated food.

Many governments have passed laws to force firms to implement traceability systems that identify weak spots and enable hazardous products to be withdrawn from the market efficiently. But rebuilding consumer trust takes time, and climate change increases the challenge. Warmer, more humid conditions accelerate the growth and spread of fungi in the environment. This poses an existential threat to the food system. Foods like apples and coffee beans susceptible to carrying the mycotoxins produced by fungal molds are particularly at risk.

So the reliability and dependability of the traceability system are largely at the mercy of the accuracy and efficiency of identification and authentication technologies. They enable customers to take into account product quality and conformity with safety and environmental standards when making purchases. Developing product identification and localization technologies advances the traceability system. Innovations like distributed ledger technologies (blockchain) and the IoT should boost companies' capability to track food, fight fraud, and reduce health risks by increasing the volume and availability of data.

Not only that, but they should help organizations achieve the SDGs of no poverty, zero hunger, and better health and wellness. Goals like developing sustainable cities and improving life below water require a redesign of the global supply chain, a wholesale shift from today's "take-make-dispose" economy to a circular one. The estimates of the amount of food wasted worldwide are well known; roughly one-third of what's produced is lost through spoilage in the supply chain and never reaches intended consumers in an edible state. Likewise, the WEF has forecast that if we keep producing (and failing to properly dispose of) plastics at predicted rates, the volume of synthetics in the ocean will outweigh the fish in it, pound for pound, by midcentury (we discuss this topic further in the chapter Living Sustainably).

Three ways the Internet of Things (IoT) is impacting food supply chains



The IoT is changing the way the world thinks about food. Aside from its crucial role as an interface between data processing and producer-based hardware such as drones, self-driving tractors, and crop monitors, it contributes equally via downstream innovation.

Smart thermostats reduce the risk of breakdowns in the cold chain during transport and delivery, and inventory sensors for warehouse management and smart appliances keep track of nearly every food item in the monitored environment. Smart appliances with these sensors will enable homes to be run efficiently and family members to keep supplies stocked. The data they generate can also be used to better predict customer orders, so retailers and manufacturers can anticipate consumer needs either at the grocery store or online. Smart consumer appliances will even alert their owners when they have a contaminated product in their home.

A good example of this in practice is DNA barcoding. While there are many different physical technologies to "connect" products, including barcodes, QR codes, and NFC tags, DNA technology can encode and decode digital information from DNA strands. Creating and applying unique, edible, flavorless DNA barcodes directly to food is an innovative next-generation analytical technique. It can enable consumers to gain full transparency into the origin of products while protecting company brands, reducing food fraud, and cutting recall costs.

Source: Getty Images

How blockchain will revolutionize food
In agriculture, blockchain can help fix inefficacies through applications like smart contracts in such areas as insurance, traceability, and payments. Agriculture-based insurance built on blockchain with key weather incidents and related payouts linked to smart contracts can be highly effective, markedly reducing time to market.

Safety is another major food industry issue, with the ability to trace products through a blockchain ledger representing another long-term opportunity. Successful pilots have been launched through IBM's Hyperledger project to track pork and other agricultural products in China. The immutable nature of transactions on the blockchain ledger also opens up applications in related high-value industries like the wine trade, as well as agriculture-related land registrations.

Chinese commerce giants Alibaba (parent of Taobao) and JD.com exemplify how blockchain-backed traceability in the supply chain can improve consumer confidence in the authenticity of food products. Beijing-based JD.com started by tracking beef from Kerchin, a company in Inner Mongolia (a province in northern China), to customers in Beijing, Shanghai, and Guangzhou.

Smallholder farmers around the world face gaps in traditional finance and thus struggle to access funding. A lack of proper credit histories, insufficient land ownership documentation, and other issues block their access to bank loans, and they are often forced to borrow funds from money lenders at much higher rates, if this option is even available. Tech-savvy agricultural entrepreneurs now use blockchain to create investment tokens and raise funds for their agricultural businesses.

What is blockchain and how does it help?

Blockchain is a distributed database that holds records of digital data or events in a way that makes them tamper-resistant. While participants in a blockchain may access, inspect, or add to the data, they cannot alter or delete what already exists. The original information stays put and leaves a permanent and public information trail of transactions, providing a verifiable record of transactions and activities occurring across complex supply chains.

The key advantages of a blockchain network include:

- **Disintermediation:** Blockchain makes the centralized server less relevant. Peer-to-peer transactions can take place without oversight or third-party intermediation yet remain protected from counterparty risks.

- **Security:** The cryptographic nature of blockchain transactions makes the network more secure than traditional databases because hash values prevent any malign user from altering the transactions.

- **Resilience:** In addition to its immutability, blockchain networks are resilient as they do not have a central point of failure. Also, given the encrypted and chain-like nature of the data blocks, any potential damage to the data would not affect records of historical transactions.

- **Lower costs:** By eliminating or reducing the need for intermediates and the costs associated with them, blockchain networks can greatly reduce transaction costs. The ability to monitor transactions in real time, for example, can reduce the effort needed to reconcile dispute resolutions.

Source: Getty Images

Bioplastics crucial in the fight against pollution

As the need to create sustainable eco-friendly products increases, how consumer goods are packaged (and disposed of) must be re-engineered as well. Biodegradable plastics could lower the volume of trash in landfills, reduce GHGs, and cut down on the plastic debris in the ocean, which causes numerous problems, from killing fish and marine mammals when mistakenly ingested to releasing toxic compounds. Smart packaging could also increase the shelf life of fresh food and reduce waste.

A recent breakthrough in producing plastics from cellulose or lignin (the dry matter in plants) is one such promising innovation. These materials can be derived from nonfood plants such as giant reed and grown on marginal land not suitable for food crops or from waste wood and agricultural by-products that otherwise serve no function. Algae and mushroom-based alternatives have also gained in popularity with the likes of Ikea.

As with all new technologies, many hurdles must be overcome before the new plastics can be commercialized. Cost is a big obstacle. Another is minimizing the amount of land and water used to produce them – even if the lignin comes from waste, water is needed to convert it into plastic. The solutions will require a combination of measures, from regulatory to voluntary changes in the ways society uses and disposes of plastics. Still, the emerging methods for producing biodegradable plastic offer a perfect example of how greener solvents and more effective biocatalysts can contribute to generating a circular economy in a major industry.

Source: Getty Images

Digital channels reshaping food retail

Entirely new business models have emerged in recent years. They demonstrate that consumers, in particular in younger generations, place greater value on instantaneous access to products and services. This on-demand principle will continue to reshape food retail dramatically. Buying a week's worth of groceries at one time is becoming a thing of the past; future consumers will demand fresh produce and want it delivered now in the format in which they will consume it.

The food delivery industry has existed for a few decades, via yellow pages and telephones; the advent of mobile phone apps has transformed the industry into a largely online market. Thanks to the success of ride-hailing platforms like Uber and Grab, and the emergence of logistics platforms, online food delivery has changed the way food is eaten. Consumers now have more food options than ever before, all at their fingertips.

Millennials and young consumers are clearly driving the trend. They order two to four times as much food online per week as those over 40 years old. The shift toward single-person households is also fueling this trend; China, where food delivery has caught fire, has almost 80m single-person households alone. Given the benefits of centralized kitchens and increased automation, ordering dinner through food delivery apps might soon be a cheaper option than preparing food at home – which could supercharge the industry's growth rates.

In the long run, the emergence of innovative logistics solutions like autonomous droids and drones may further boost the industry's last-mile coverage. Online food delivery is the largest segment within the food innovation theme today, both in terms of revenues and funding. We expect the segment to continue growing thanks to ongoing consumerization of digital services and larger order sizes.

Chapter 7

Investing in food innovation

Whether you're a farmer looking for the latest tools to boost crop production sustainably, or a professional investor looking for the next leap in innovation, we believe there is no better time to invest in food and agriculture.

Vegetable processing plant in Canada

Source: Getty Images

Factory worker operating a conveyor belt in a vegetable processing plant.

While the food supply chain has been around for centuries the need for innovation remains as great as ever. Whether you're a farmer looking for the latest tools to boost crop production sustainably, or a professional investor looking for the next leap in innovation, we believe there is no better time to invest in food and agriculture. As digital transformation takes hold and the supply chain integrates vertically, opportunities for investment in the sector by non-traditional investors increase.

Traditional investment in agriculture consisted of real assets, or a fund that invested in them. The hybrid nature of agricultural assets (which have the characteristics of both property and infrastructure investments) makes them difficult to assess and manage, exacerbating their hit-or-miss nature.

Unlike in previous phases of technological development though, innovation this time is being introduced principally through software and data channels, an area fewer industry incumbents have experience in. As you consider investing in the food supply chain, a tech startup, or the launch of your own, it's important to understand some market idiosyncrasies.

Agritech financing breaks records

Historically, 95% of agritech innovation has been commercialized via M&A as technologies were incorporated into the industry by established companies like John Deere, Case NH, etc. These firms have been market makers for innovators, but this model is swiftly changing.

Agritech startups enjoyed another record year of financing in 2018. According to research by equity crowdfunding platform Agfunder, deals completed rose by 43% y/y to USD 16.9bn from USD 11.8bn in 2017. Upstream and downstream segments grew at a similar 43–44% y/y pace that was broad based.

The agritech ecosystem is beginning to scale up. In both 2017 and 2018, late-stage transaction volumes rose. Unlike other industries, where late-stage funding has been on the rise and early-stage funding activity has been in decline, interest in seed-stage deals in the agritech industry remains solid. Activity rose at a mid-teen percentage rate in 2018, accounting for 803 out of 1,450 deals in the agritech industry, according to AgFunder, with deal volume rising by 50% y/y to USD 685m.

By region, the US, China, and India are the top three markets, respectively. They account for almost 80% of global agritech funding. By segment, the downstream online food delivery segment is, unsurprisingly, the largest segment by value; within upstream segments, Farming 4.0 and plant-based protein companies continue to draw plenty of interest.

As agritech continues to mature as a sector, Agfunder believes more nine-figure valuations are likely at the early stage for the most promising applications. As investors explore capital-light subsegments within agritech, deal flows have also been solid in plant sciences and animal health startups.

Two breeds of startups

On the startup side, two agritech types have emerged; those that disrupt and those that build on existing technologies, for example, what John Deere, Case NH, and other corporations are doing. The role of corporate venture capital in agritech remains crucial, and agritech M&A has certainly picked up, leading to increased interest.

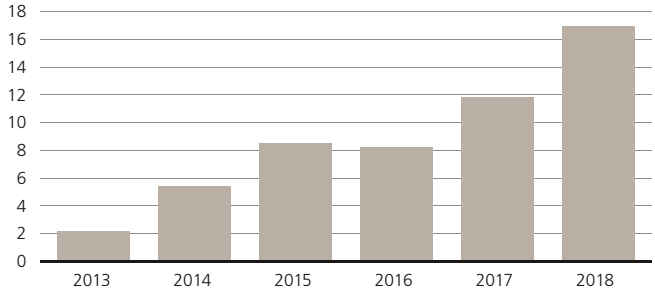
Most companies in agritech are still quite early stage and don't have significant cash flow yet. Even established agri-corporations are just beginning to make acquisitions rather than pursue in-house R&D. The educational component of agritech is important for investors in general, as the field doesn't fit neatly into traditional industry segments like biotech or fintech, etc., where some investors feel more comfortable.

Beyond Meat and other nontraditional protein companies are benefiting from a boom in the consumption of plant-based products, primarily in developed nations. Industries are being forced to evolve alongside opportunistic investors who can capitalize on growth in those areas. Tyson's announcement that it will offer plant-based burgers of its own illustrates that traditional industries are being disrupted.

Agritech in numbers

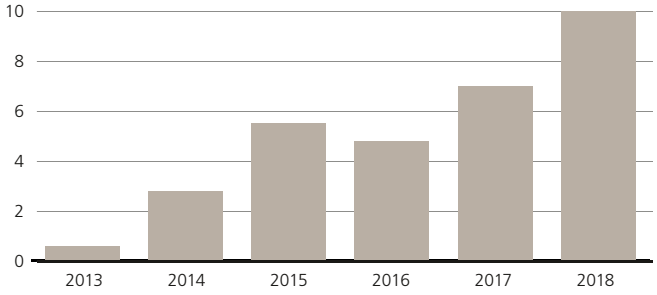
Global funding to agritech startups

In USD bn



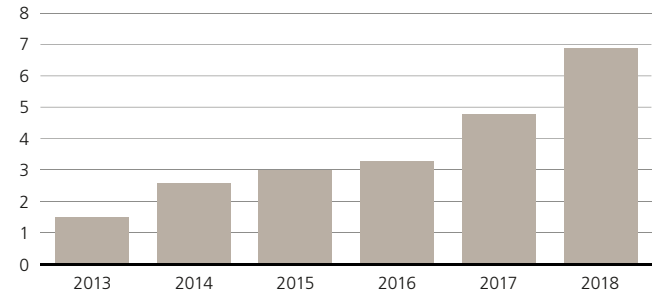
Global funding to downstream agritech startups

In USD bn

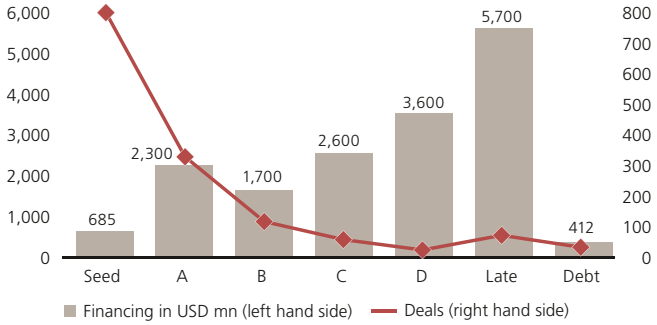


Global funding to upstream agritech startups

In USD bn

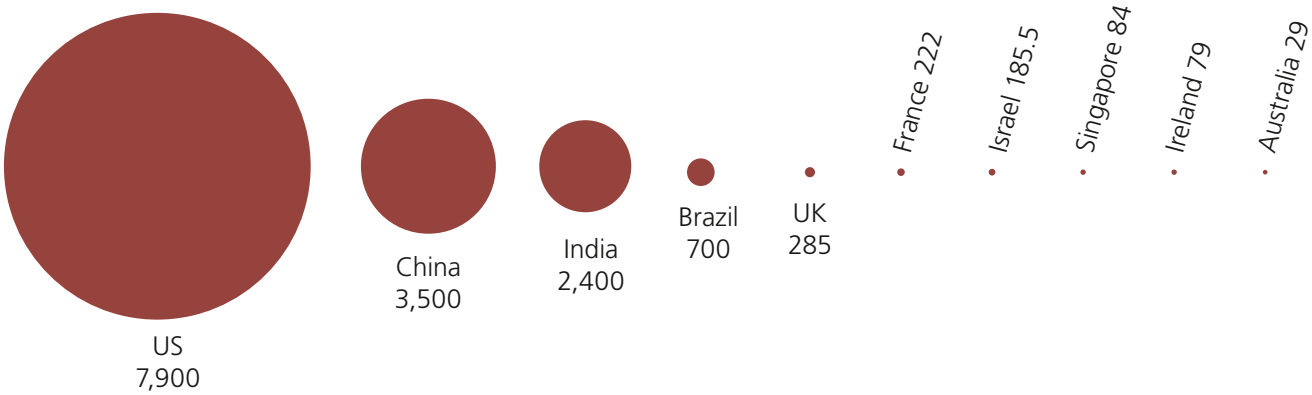


Overall 2018 agritech deal volume and activity by stage



Global agritech investments by region

Investment in USD m



Source: AgFunder, UBS, as of April 2019

How much could it all be worth?

Overall, we estimate the food innovation opportunity represents a USD 700bn market by 2030. We expect it to grow more than fivefold, at a 15% CAGR, from USD 135bn in 2018. We divided the addressable market into five major segments. We expect the plant-based meat market to expand from USD 4.6bn in 2018 to USD 85bn at the end of the next decade as penetration rates increase from 0.4% to 6%. Our estimates may prove conservative if plant-based meat adoption accelerates thanks to innovation and increasing consumer awareness.

Farming 4.0 is another promising segment within that timeframe. We anticipate it expanding from a USD 15bn market in 2018 to USD 90bn. Despite a mid-teen CAGR, its penetration rates, which we expect to increase from 0.3% to 1.5%, are likely to remain much lower than those of the other digital transformation trends like fintech and e-commerce.

Online food delivery is set to be the largest segment, expanding from a market worth USD 60bn in 2018 to USD 365bn, a mid-teen CAGR, according to our forecasts. Emerging markets, improving logistics, and a structural shift from offline to online food delivery are likely to drive this growth.

Our combined industry forecasts assume a mid-teen CAGR that we consider reasonable. The key downside risks to our estimates include slower-than-expected adoption of plant-based meat in emerging markets and logistical setbacks, unfavorable economics in food delivery, and data security risks for Farming 4.0.

Upside risks include widespread adoption of plant-based meat sparked by millennials and EM consumers, greater network effects in the food delivery industry resulting in greater-than-expected repeat orders, and higher-than-anticipated efficiency gains in Farming 4.0. resulting in more orders.

Investing in sustainable food and agriculture

We see the investment community, particularly within the fields of sustainable, responsible, and impact investing, is demonstrating an increasing appetite for investing in sustainable agriculture and food systems across asset classes. Sustainable agriculture refers to a diverse array of farming systems that enhance the biodiversity of farming landscapes, improve soil health and the water cycle, and strengthen the resilience of rural agrarian communities.

These outcomes also align with UN Sustainable Development Goals, which sustainable, responsible, and impact investors are increasingly integrating into investment decision-making frameworks. Furthermore, when taking a total portfolio approach to sustainable agriculture, it provides investors with a constructive way to grapple with the widest array of investment opportunities because each asset class presents its own specific opportunity set – whether financing small-scale local food systems or intervening in large-scale global supply chains.

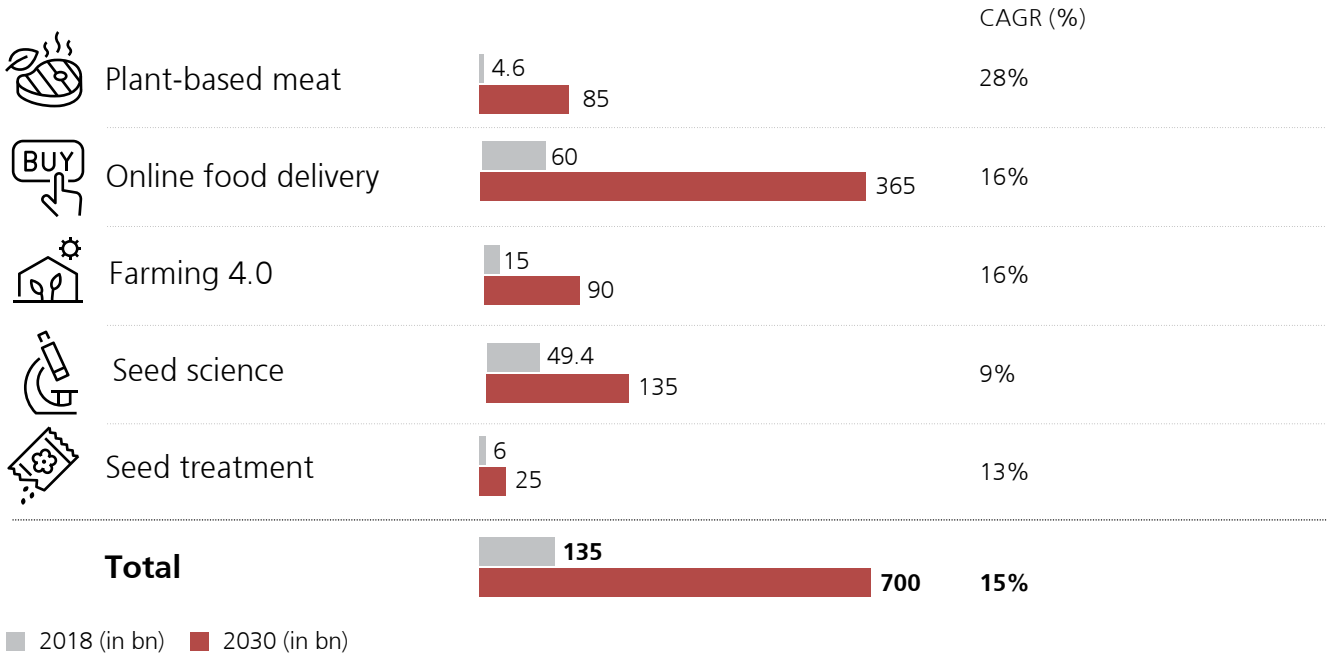
Investing in sustainable food and agriculture can be narrowly focused, say in a farmland fund or a food-focused debt fund. Likewise, it can be part of a more holistic approach: integrating environmental, social, and governance themes into investments that relates to climate, water risk, labor and human rights, and that has direct impacts on people and places.

Investment implications

Unlike other megatrends, the food innovation industry is mostly represented by startups, business units that are part of major food companies, and recently listed companies in fast-growing industries like food delivery and plant-based meat. As a result, to benefit from the trend, investors should diversify their exposure and own listed and unlisted companies alike. The industry is likely to consolidate in the next three to five years, in our view, which also provides interesting opportunities from an M&A perspective.

How big is the addressable market?

Revenue opportunity



Sources: Company reports, Bloomberg Intelligence, UBS estimates, as of June 2019

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