

An Ever-Green Revolution

Why Ending Factory Farming Holds The Key
To Feeding Humanity

June 2023

Foreword

This is a story of best intentions and bleak repercussions – a story of how abundance was achieved and then abused; of how astonishing success gave way to grim failure; and of how the dream of a would-be utopia crumbled, leaving a devastating dystopia to rise in its place. It is the story of the Green Revolution in food production – and the hope of a new revolution that is still to come.

The Green Revolution began in earnest in the 1940s. Although it helped tackle the scourge of hunger in the battle-scarred aftermath of World War II, it can now be seen as a monumental example of the law of unintended consequences.

The original aim was to feed around 2.5 billion people – the global population in 1950 – by massively increasing crop yields. Today, conceivably, the same idea could solve world hunger and feed a global population of more than eight billion people¹ and possibly many more – but something very different has happened. Now, each year, the enormous surpluses that the Green Revolution was pivotal in generating are instead used to feed almost 80 billion animals – most of them destined for slaughter under the intensive, industrialised farming regimes that have dominated food production for over half a century.

The cruel irony is that the Green Revolution has thus come to underpin a food system that works against us, not for us. Worldwide, aside from its horrendous impacts on animal welfare, factory farming emits more greenhouse gases than the whole transport sector; is the main cause of deforestation; is the number-one user of fresh water and antibiotics; and is a leading source of epidemics and pandemics. The resulting damage and dangers can no longer be ignored.

This paper explains how we went from Green Revolution to what United Nations Secretary-General António Guterres has called a “code red” for our planet and its inhabitants. It also explains how the seeds of a new revolution – an Ever-Green Revolution – are now being sown by pioneers in areas such as plant-based proteins, clean meat, sustainable feed and net-zero farming.

It is an exercise in root cause analysis. Like psychoanalysis, it represents a concerted attempt to understand the root cause of a problem and to be better able to identify and implement a genuine solution. The fundamental aim is to address underlying issues, not to focus on ad-hoc symptoms as and when they appear.

As one of our guest contributors remarks in the following pages, the human race has a long history of innovating its way into trouble. Thankfully, as he also points out, it has a long history of innovating its way out again as well.

Not least amid unprecedented levels of food insecurity in the face of post-pandemic economic turmoil, unravelling supply chains, escalating geopolitical tensions and the return of conflict in Europe, we now need to innovate our way out of trouble once more. And there is growing reason to believe we will.

Within the next year, for the first time ever, the Food and Agriculture Organisation of the United Nations is set to unveil a plan to make the food system more sustainable. Announced at COP27, this milestone comes in direct response to FAIRR-led investor pressure². Its goals will include alignment with the Paris Agreement’s primary objective of limiting global warming to 1.5°C above pre-industrial levels. It is already being described as a “roadmap” for companies and the investment community.

Such a development reinforces my conviction that we can finally build a food system capable of safeguarding our collective future rather than placing it in ever-mounting peril. Provided we avoid the mistakes of the past, we can deliver the positive change that is so desperately needed. We may even discover, as I believe, that at last ending world hunger is far easier than we might dare imagine and that the answer is entirely in our own hands.

Jeremy Collier

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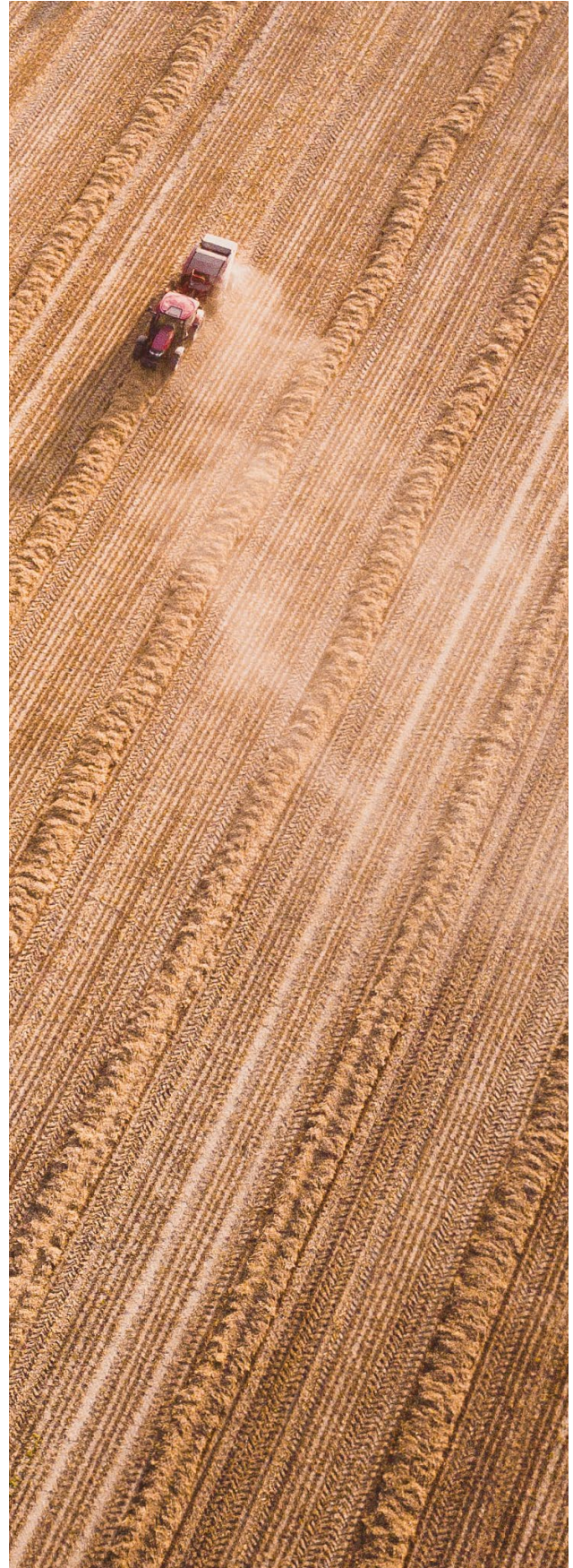
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1 Executive summary

- We consider the long-term consequences of the Green Revolution, which was set in motion after World War II to address issues around resource scarcity and hunger.
- We accept the Green Revolution began with the best intentions and initially achieved its objectives, but we argue that its unforeseen negative impacts have been substantial.
- The long-term consequences have included the crucial role of enhanced crop yields in fuelling factory farming's rise amid unhealthy higher global demand for meat and dairy products.
- The now-dominant factory farming sector is today directly linked to climate change, highly resistant pathogens and other existential threats facing the planet and its inhabitants.
- It is therefore possible to trace many of the most significant problems currently facing humanity back to a transformative event once celebrated as an enduring solution.
- We suggest the revolution lost its way because of abundance, greed, the entrenchment of suboptimal practices and the use of innovation to maintain the status quo.
- With factory farming at its heart, this status quo has now become unsustainable and is in many ways devoid of any semblance of what we today think of as "green".
- What remains of the Green Revolution must urgently give way to an Ever-Green Revolution in which agriculture clearly serves to safeguard rather than threaten the future.
- With technology increasingly disrupting the global food system, investors and the power of ownership have a major role to play in ensuring change is both positive and lasting.



2 Introduction: beyond the Green Revolution

Imagine a world where hunger has been eliminated and resource scarcity is a distant memory. Landscapes are unscarred by “progress”, ecosystems are gloriously intact, and the term “global warming” has not even been coined – let alone entered everyday parlance. Agriculture is sustainable, conducive to human health, sympathetic to animal welfare and expressly geared towards the survival of the planet and its inhabitants.

Now imagine a world where almost seven hundred million people are undernourished and targets for eradicating the scourge of hunger by 2030 are thought wildly optimistic. Resources are wasted, biodiversity is in crisis, and everywhere – land, sea and air – is poisoned. Agricultural practices have become so intensive, so brutally industrialised, that they are central to the numerous existential threats confronting humanity and the domain over which it supposedly presides.

Today, in 2023, the first of the above scenarios represents a utopia that might have been realised but which somehow slipped through our collective grasp. The second represents not just a dystopia but the terrible reality that has taken shape during the 70-plus years since what was heralded as the Green Revolution.

Our starting point for this paper is therefore essentially a hypothetical question: what if the Green Revolution had achieved only what it set out to accomplish? Although there can be no definitive answer, we can at least infer what has been good and bad about the longer-term development of agriculture in response to population growth and other major dynamics – and we can determine the lessons that should be learnt.

We take “Green Revolution” to mean efforts to augment food supply through the enhancement of crop yields worldwide in the decades following World War II. This means answering our fundamental question requires us to chart agriculture’s transformation over the period from roughly the middle of the 20th century to the present day.

Nobody disputes that this transformation began out of necessity and with the best intentions, but there can also be little doubt that it has brought unforeseen consequences. Foremost among these has been another revolution: the rise of factory farming. This paper argues that the Green Revolution would have thrived without factory farming but, crucially, factory farming and all the risks it is now known to entail could not have thrived without the Green Revolution – alongside a further 20th-century revolutionary discovery, antibiotics.

We have, then, three tasks:

- To explore how we arrived at where we are today
- To reflect on where we could have been if the Green Revolution had unfolded as hoped
- To consider where we might go from here if we want to reorient the course of food production and ensure sustainability for the agricultural industry and its myriad stakeholders

A common theme throughout our analysis is the idea of a journey – one stretching from the problem of increased demand to the ideal of genuine sustainability. The former was the catalyst for the Green Revolution and is still with us today. The latter remains an imperative yet elusive goal.

The Green Revolution was necessary, because it helped stave off the terrifying prospect of food scarcity; but it somehow took turns that would prove ever more damaging over time. We believe these turns require scrutiny and explanation. In this paper we aim to better understand the past so that we might better safeguard the future.

“The Green Revolution was necessary, but it somehow took turns that would prove ever more damaging over time.”

From Green Revolution to *Ever-Green Revolution*: killer stats that investors cannot ignore

- In 1955, when the Green Revolution was still in its infancy, the global population was around 2.8 billion. Today, with the Green Revolution seemingly at a dead end, it stands at more than eight billion.
- In 1963, when the Green Revolution was taking hold around the world, there were approximately seven billion cattle, pigs, sheep, goats and poultry. Today around 80 billion are slaughtered for food each year.
- Meat production has more than trebled during the past half-century, reaching 340 million tonnes in 2018. This trend is expected to grow, especially in low-income and middle-income countries.
- More than 70% of livestock worldwide is now factory-farmed. The figure in the US is thought to be more than 99%.
- Thanks to this mass industrialisation, there are feedlots that can hold more than 100,000 cattle, pig farms that can contain thousands of hogs and poultry plants that can house half a million chickens.
- The superabundance produced by the Green Revolution has been used mainly to feed livestock, thereby propping up what is now clearly an unsustainable model of food and agriculture. Rather than feeding around 80 billion animals destined for slaughter, it could instead have been used to feed an ever-growing global population.
- At present, with more than three quarters of farmland worldwide given over to livestock, only around half of the crops grown are used to feed people directly.



3 Best intentions and unforeseen consequences

3.1 A second Mexican revolution

Humanity's dread of having too many mouths to feed was first famously articulated in *An Essay on the Principle of Population*, published in 1798, in which Thomas Malthus warned population growth must inevitably outstrip food production. There have since been many "Malthus moments", one of the most significant of which came after World War II.

The end of the conflict saw industrialised nations revert to a peacetime economy and many of their developing counterparts, having gained independence, assume more control over their agricultural practices. The advent of a baby boom, coupled with improvements in medicine, led to substantial rises in population growth globally. Meanwhile, international relations – both political and with regard to trade – were being redrawn.

Against this backdrop, many countries faced the daunting challenge of attaining self-sufficiency. Truly remarkable progress in this respect was first witnessed in Mexico, whose agricultural output increased fourfold between 1940 and 1965³.

The principal architect of this turnaround was American scientist Norman Borlaug, who took up an agricultural research position in Mexico after gaining a PhD in plant pathology and genetics in 1942. Borlaug created novel varieties of wheat whose high yields and resistance to disease, especially in combination with new machinery, quickly allowed Mexico to produce more than enough to feed its own citizens.

This was the start of what would become known as the Green Revolution, which spread far beyond its birthplace throughout the 1950s and 1960s. Like Mexico, the US⁴ went from net importer to net exporter in around 20 years^{5,6}. India was able to avoid mass famine and eventually used another of Borlaug's innovations to become one of the biggest producers of rice; Bangladesh and Pakistan also averted potentially devastating food crises. South-East Asia, Africa and the Middle East followed in doubling or even trebling yields.

In 1970, in recognition of his contribution to ensuring the security of the world's food supply, Borlaug was awarded the Nobel Peace Prize. He missed an early-morning call from Norwegian officials and eventually learnt of the honour while tending a field in the Toluca Valley, around 30 miles from Mexico City.

Delivering his Nobel Lecture, Borlaug declared: "The first essential component of social justice is adequate food for all mankind." While conceding the term "Green Revolution" might be "premature, too optimistic or too broad in scope", he described the progress resulting from his work as "spectacular", "phenomenal" and "tremendous"⁷.

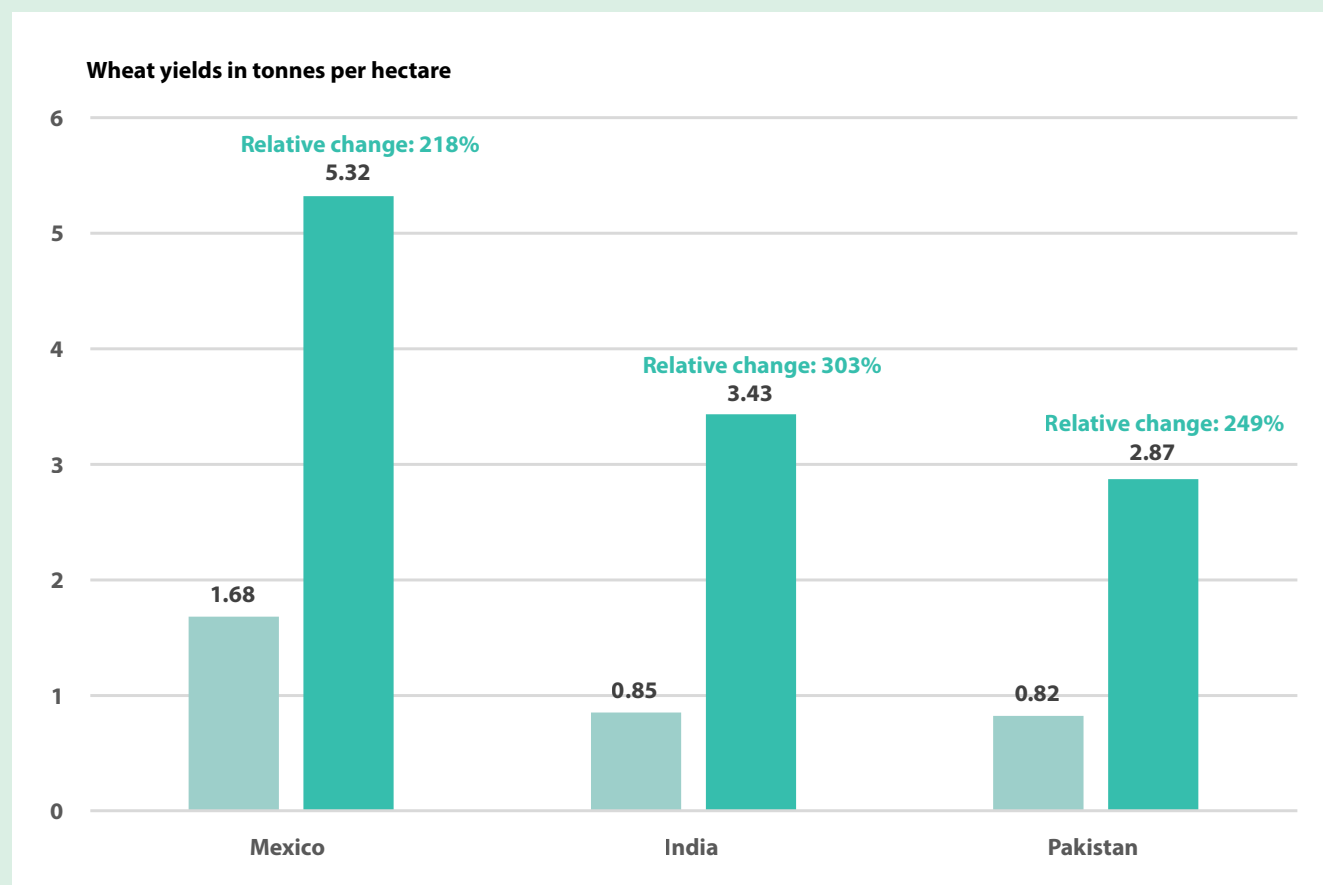
More than half a century later – and over a decade after his death – the "miracle" crops that Borlaug and his fellow researchers were able to develop through selective breeding continue to hold sway over agricultural practices around the globe. Their particular attributes still dictate the use of fertilisers and irrigation, and their general reliability still determines the number of varieties grown.

Yet closer examination suggests many aspects of the Green Revolution did not pan out as expected. The radical transformation of agriculture after World War II might have seemed worthy of a Nobel Peace Prize in 1970, but the passing of time has arguably cast it in a strikingly different light.

"The radical transformation of agriculture after World War II might have seemed worthy of a Nobel Peace Prize in 1970, but the passing of time has arguably cast it in a strikingly different light."

“Miracle” crops and mounting yields

The chart below shows the huge growth in wheat yields in Mexico, India and Pakistan as a result of the Green Revolution. Mexico witnessed the biggest turnaround in terms of sheer quantity, while India and Pakistan were able to avoid famine.



Source: *Our World in Data*: “Crop yields”, June 2021



3.2 Unfulfilled promise

The longer-term impacts of the Green Revolution were first seriously questioned in the 1980s. They have been fiercely debated ever since. As stated earlier, nobody denies the innovations introduced by Borlaug and others were implemented with the best of intentions. What is in dispute is whether, on balance, the envisaged benefits have outweighed the unintended consequences.

We first need to return to the above observation about the Green Revolution's enduring influence on agricultural practices. The key point is that this influence is no longer positive. A wealth of research indicates what was once a reliance on fertilisers, pesticides and irrigation has become a highly damaging *overreliance*⁸ – one that has wrought a devastating impact on soil fertility and erosion, vulnerability to pests and genetic diversity⁹. The United Nations Environment Programme has warned the large-scale use of chemicals in food production may even make humans more vulnerable to a range of “adverse health effects” – including breast cancer, abnormal growth patterns and damage to immune functions – while pollution stemming from agriculture, as we explain in more detail in section 4.2, poses numerous risks both to ecosystems and to human health¹⁰.

These issues alone show the Green Revolution has not proven sustainable in the strictest sense. They also show, as the Food and Agriculture Organisation of the United Nations has stressed, that “transformative change” comparable to that seen in the 1950s and 1960s is now desperately needed again¹¹.

More broadly, the Green Revolution held hopes for the elimination of hunger. Although some estimates posit that a billion lives have been saved, the mere existence of United Nations Sustainable Development Goal (SDG) 2 – “End hunger, achieve food security and improved nutrition and promote sustainable agriculture” – signifies that these hopes have still to be fully realised¹².

Each of the 17 SDGs has a target date of 2030. The likelihood of SDG 2 being fulfilled by then is now thought to be extremely remote¹³. In 2021 the Global Hunger Index reported that 37 countries had “serious” levels of hunger and 10 had “alarming” or “extremely alarming” levels; that more than 650 million people would be undernourished by 2030; and that “the fight against hunger is dangerously off track”¹⁴. The Food and Agriculture Organisation has said the scourge of hunger is unlikely to be eradicated even by 2050¹⁵.

In addition, at least over the longer term, the Green Revolution may have added to rather than alleviated poverty. There are two sides to this argument, both of which require consideration.

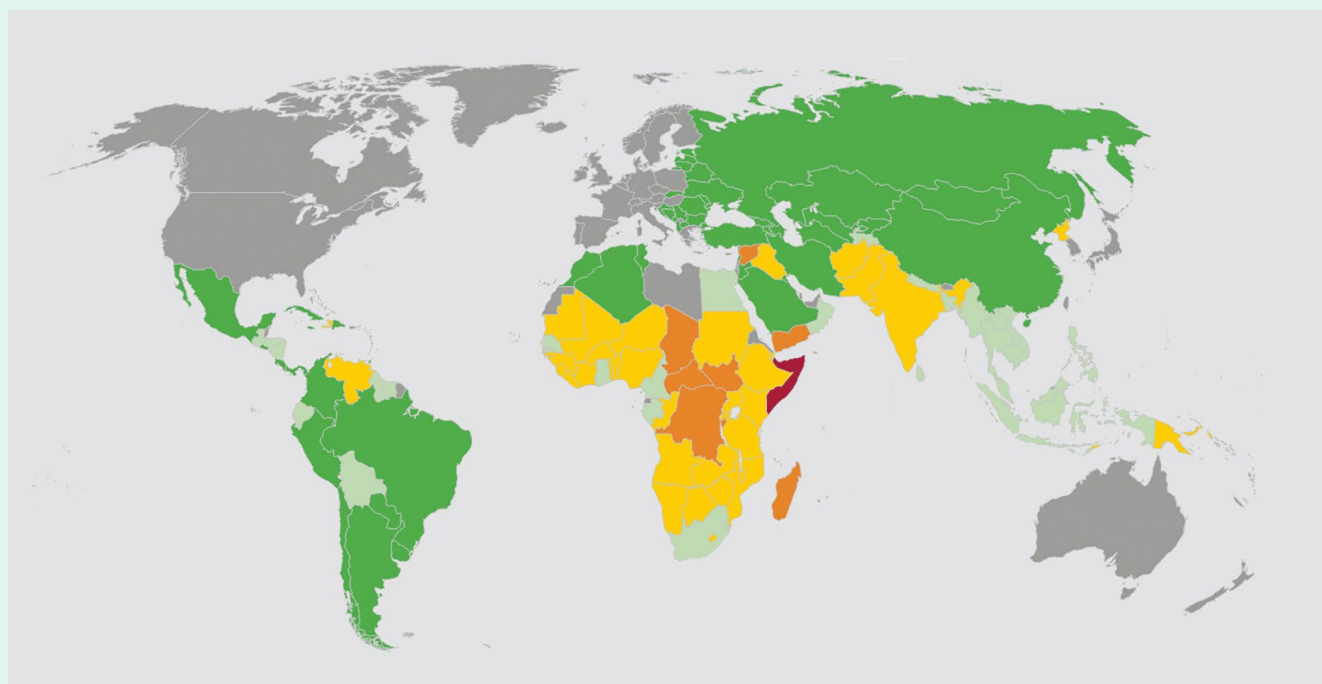
The conventional development paradigm, as outlined by the World Bank, requires agricultural systems to become more capital-intensive, more productive and better integrated with other industries. Small-scale farmers gradually diversify their sources of income and employment, and some leave agriculture completely and find job opportunities elsewhere¹⁶. Proponents believe the Green Revolution enabled this to happen.

An alternative analysis holds that the corollaries of the Green Revolution made the poor even poorer. The biggest producers enjoyed the benefits, including economies of scale and generous subsidies, as agriculture boomed; by contrast, the mounting costs associated with innovation placed the means of achieving success beyond the reach of many small farmers. According to critics such as Indian ecologist Vandana Shiva, prosperity for many was “narrow and short-lived” – and development gave way to “social disintegration and violence”¹⁷.

Crucially, although they represent opposing views, these interpretations are united in the prominence they give to a decisive trend: the rise of factory farming. Building on the Green Revolution, agricultural production trebled between 1960 and 2015¹⁸ – during which period, with global demand for meat and dairy products also growing enormously, the word “intensive” became a mainstay of the industry's lexicon. As we will see next, it is this unwelcome repercussion that has dragged us ever further from the utopia that once seemed possible. To quote a United Nations Environment Programme analysis: “Decades of industrial farming have taken a heavy toll on the environment and raised some serious concerns about the future of food production.”¹⁹

The persistent blight of hunger

The chart below shows the Global Hunger Index's 2021 assessment of hunger around the world²⁰. Scores are calculated on the basis of four indicators: undernourishment, child wasting, child stunting and child mortality. The Index's authors say humanity is not on track to achieve zero hunger by 2030.



GHI Severity Scale

≤9.9 Low	10.0–19.9 Moderate	20.0–34.9 Serious	35.0–49.9 Alarming	≥50.0 Extremely alarming
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Source: Global Hunger Index: 2021 Global Hunger Index: Hunger and Food Systems in Conflict Settings, 2021

“The Green Revolution held hopes for the elimination of hunger. The mere existence of United Nations Sustainable Development Goal 2 signifies that these hopes have still to be fully realised.”

4 Turning points and tipping points

4.1 Then and now

“If you desire peace,” Borlaug said in his Nobel Lecture, “cultivate justice. But at the same time cultivate the fields to produce more bread, otherwise there will be no peace.” This remark chimed with the prevailing sentiment during the late 1960s and early 1970s, when the Malthusian spectre of resource scarcity continued to loom large.

One of the most celebrated articulations of the threat came from American biologist Paul Ehrlich, whose best-selling book, *The Population Bomb*, was published in 1968 – two years before Borlaug addressed the Nobel Committee. Prophecying a desolate future in which demand would hopelessly exceed supply, Ehrlich insisted no number of emergency programmes – however swiftly implemented – could avert imminent crisis and societal collapse. “Hundreds of millions of people are going to starve to death,” he wrote. “Nothing can prevent a substantial increase in the world death rate.”²¹

In 1955, when the Green Revolution was in its infancy, the global population was around 2.8 billion. By 1970, when Borlaug was collecting his Nobel Peace Prize and Ehrlich was predicting all-encompassing cataclysm, it stood at around 3.7 billion. It is now above eight billion and is expected to top nine billion by 2050²².

This trajectory has consistently fuelled what Ehrlich called “the battle to feed all of humanity”. It is a battle that is still being waged, with demand for animal protein rising in concert with per capita incomes and urbanisation in many parts of the world²³. This trajectory has consistently fuelled what Ehrlich called “the battle to feed all of humanity”. It is a battle that is still being waged, with demand for animal protein rising in concert with per capita incomes and urbanisation in many parts of the world²⁴. Meat production has more than trebled during the past 50 years, reaching 340 million tonnes and involving the slaughter of around 80 billion animals in 2018²⁵, with the trend for growth expected to continue – particularly in low-income and middle-income economies²⁶.

We have seen how the work of Borlaug and his peers contributed to the necessary response to “the battle to feed all of humanity”, but it was not only crop yields that boomed throughout the second half of the 20th century. Alongside the Green Revolution, factory farming emerged as a further “solution” in the quest to feed billions.

Borlaug could scarcely have dreamed of this gruesome ramification. Like his pioneering research, the large-scale industrialisation of farming commenced after World War II. The process originated in the US and was

soon adopted by other developed nations. Powered by mechanisation, livestock production was cranked up – figuratively and literally – as more and more people found themselves able to afford meat and dairy. Traditional methods gave way to intensive systems, ushering in a raft of new normals.

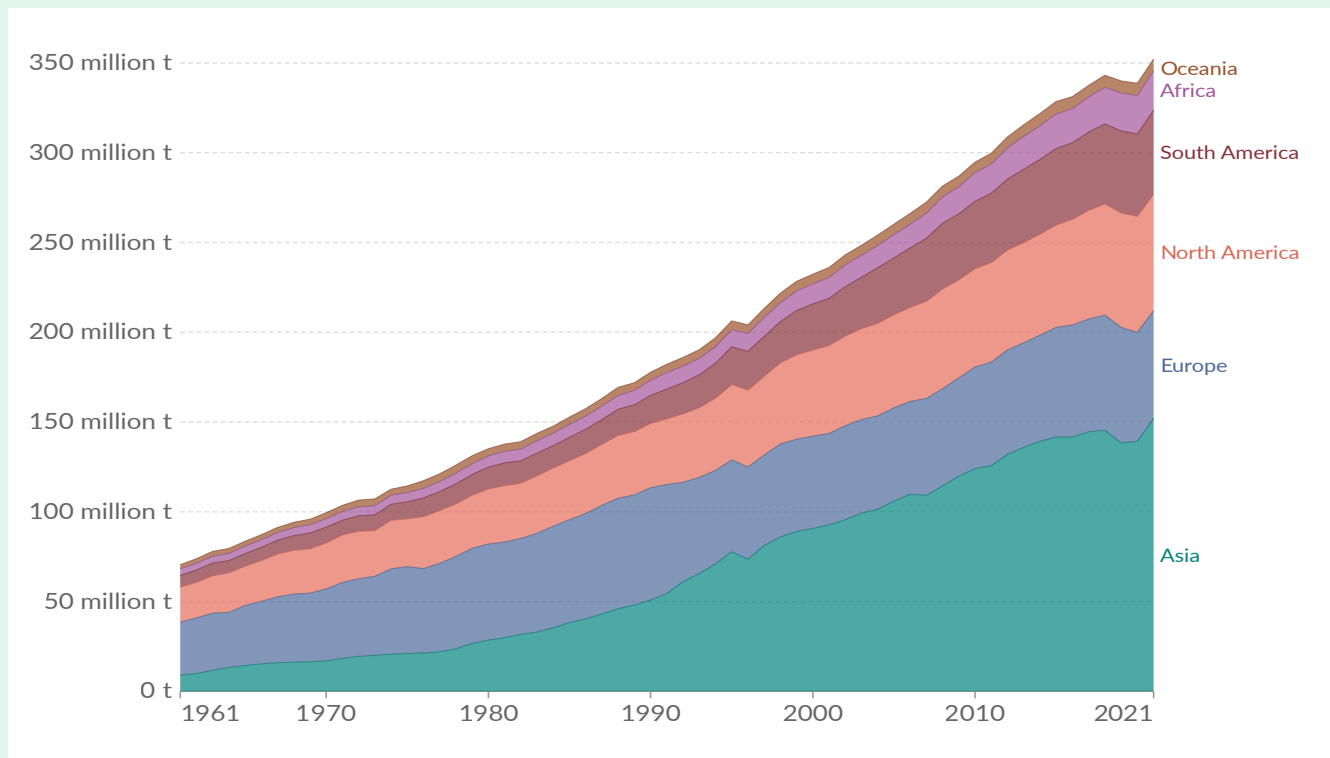
There were approximately seven billion cattle, pigs, sheep, goats and poultry in 1963; there were around 25 billion 50 years later. The number was rising rapidly even by the early 1970s, at which stage the rate of growth in global livestock production was already starting to outstrip the rate of human population growth; the divergence has widened ever since. The American Society for the Prevention of Cruelty to Animals has estimated that more than 70% of livestock is now factory-farmed, with the figure in the US reckoned to be over 99%²⁷. Today there are feedlots that can hold in excess of 100,000 cattle²⁸; there are pig farms that can contain many thousands of hogs²⁹; and there are poultry plants that can house half a million chickens³⁰. Small-scale farming has been marginalised, and corporations have become dominant. In short: there are now many more animals and many fewer farms.

Confronted by the dynamics previously experienced by their developed counterparts – specifically, sizeable increases in population, incomes and urbanisation – emerging economies have followed the same curve. China is leading the charge, with many of the Green Revolution’s poster children – including South America and India – adopting this form of industrialisation at pace and scale. With eating meat historically seen as an indicator of middle-class status³¹, it is now over 10 years since the Food and Agriculture Organisation warned the expansion of the livestock sector was “exerting substantial pressure on natural resources”³² – and this pressure is only intensifying further as we move towards the second quarter of the 21st century.

Since both are components of the same industry, it was perhaps inevitable that the Green Revolution and factory farming would intersect. Ultimately, the former underpinned the latter: the spread of factory farming relied on a huge supply of feed, and the Green Revolution provided it. Most cultivatable land is now used for crops to feed livestock or for processed food. We have gone from dearth to surplus, and we are using that surplus principally to perpetuate an alarmingly unsustainable model of agriculture. Today, despite Borlaug’s vision, a glut that might have fed eight billion people is instead being used to feed 80 billion animals.

Meat production: grim evidence of factory farming's rise

The unprecedented crop yields produced by the Green Revolution were increasingly used to feed factory-farmed livestock rather than to directly feed the global population. Concurrently, as shown in the chart below, meat production rose steeply. As we will discuss next, this trajectory – indicative of the spread of factory farming – has added to the world's problems instead of helping solve them.



Source: *Our World in Data*: "Global meat production, 1961 to 2020", November 2019

“Ultimately, the Green Revolution has served to underpin factory farming. A glut that might have fed eight billion people is instead being used to feed 80 billion animals.”

4.2 From mitigant to accelerant

The broader context in which agriculture must function has also shifted enormously since the birth of the Green Revolution – and especially during the past half-century. This truth is key to understanding how what was once hailed as a harbinger of sustainability in terms of food supply³³ has steadily metamorphosed into a vehicle of *unsustainability* in many other respects.

The Green Revolution got under way in the wake of one existential threat, World War II, and in the face of another, the prospect of having too many mouths to feed. Today there are multiple existential threats, all of them closely related, and the grim actuality is that the practices that dominate agriculture – as to some extent dictated by the Green Revolution – are inextricably interwoven with almost every one of them.

Climate change is the most obvious. Almost 15% of all anthropogenic greenhouse gas (GHG) emissions – that is, those caused by human activity – come from livestock, and the Food and Agriculture Organisation has highlighted “a direct link between GHG emission intensities and the efficiency with which producers use natural resources”³⁴.

In 2013, in a report entitled *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*, the Food and Agriculture Organisation suggested significant reductions in emissions were “within reach”. Such optimism has proven false. US-based sustainability advocacy group Ceres has condemned the industry as “the largest-emitting sector that doesn’t have a low-carbon plan”³⁵, while the 2020 edition of the Collier FAIRR (Farm Animal Investment Risk and Return) Protein Producer Index categorised 86% of businesses surveyed as “high-risk” in this regard³⁶.

As touched on earlier, factory farming has taken its toll on the environment in other ways. Greater use of natural resources, along with ever-distending supply chains, has also helped push the planet nearer to oblivion. Nearly half the forests that once covered the Earth have been destroyed³⁷. Groundwater sources are being depleted at a startling rate³⁸. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, more than a third of the world’s land surface and nearly three quarters of freshwater resources are now devoted to crop or livestock production³⁹. The health of the ecosystems on which all life depends has never deteriorated so quickly, leaving biodiversity in virtual freefall and around a million species in the shadow of impending extinction⁴⁰. Trucost, a division of S&P

Global Market Intelligence, has calculated industrialised farming practices cause more than \$3 trillion per year in environmental impact worldwide⁴¹.

In addition, as recent events have underlined, the deliberate homogenisation of livestock – most notably through the use of antibiotics⁴² – has turned factory farms into breeding grounds for pathogens. The possibility of transmission from animals to humans provides a patent link between modern-day agricultural methods, the occurrence of zoonotic infections and the risk of another global health crisis⁴³. The World Health Organisation has warned antimicrobial resistance “threatens the achievements of modern medicine”⁴⁴; the Food and Agriculture Organisation has suggested resistant infections could kill more people than cancer by 2050⁴⁵; and FAIRR revealed in 2020 that over 70% of agricultural businesses were at high risk of fostering future pandemics⁴⁶.

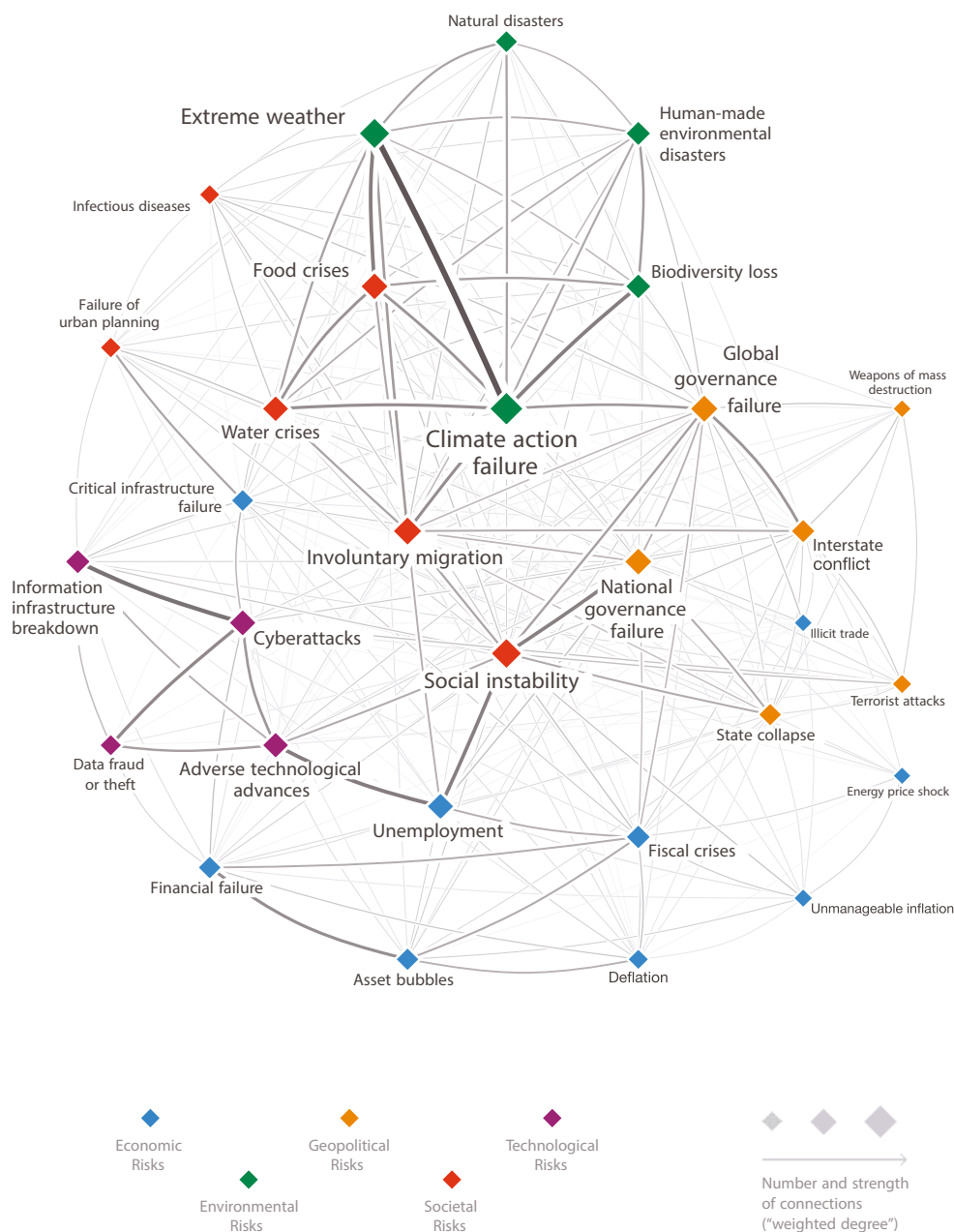
The World Economic Forum has charted how the existential threats confronting the planet and its inhabitants have become increasingly related to the natural realm. While economic, geopolitical and societal concerns dominated only a decade ago, almost every one of the 10 biggest risks detailed in the most recent editions of the Forum’s *Global Risks Report* – including climate action failure, environmental disasters, extreme weather, water crises, biodiversity loss and infectious diseases – are linked to nature⁴⁷.

The Forum uses the science of complexity to present these threats. Such an approach enables the visualisation of a global nexus of individual components and their interactions. The result, as depicted in the illustration below, offers an arresting snapshot of what has become known as interconnected causality.

Two points in particular may be worthy of attention. The first is that anything in any way associated with climate change and other environmental issues is central to the nexus. The second is that food crises represent another major hub from which multiple spokes emanate. Overall, the implications are manifest: agriculture as we know it today – a product of the Green Revolution – is a part of the problem rather than a part of the solution.

What tangled webs we weave

The World Economic Forum frames the risks facing the planet and its inhabitants through the prism of interconnected causality. This is the idea that negative impacts in one area will lead to negative impacts in others. As a major contributor to climate change, biodiversity loss, infectious diseases and other concerns, factory farming – a phenomenon made possible by the Green Revolution – is heavily entwined in this destructive nexus.



Source: World Economic Forum: *The Global Risks Report 2020*, 2020



*“Today there are multiple
existential threats, and the
practices that dominate
agriculture are inextricably
interwoven with almost every
one of them.”*

5 Drivers of dystopia

5.1 The normalisation of deviance

We mentioned earlier the notion of a journey – one beginning with the imperative of meeting increased demand and culminating in the ideal of truly sustainable food production. We also posited that the Green Revolution set out on this journey with the best intentions but took several fateful turns that would prevent it from arriving at its desired destination.

As discussed in the preceding chapters, one potential turning point came when the unforeseen consequences of the Green Revolution started to become apparent. This may have happened as soon as the 1970s; it was certainly a subject of debate by the 1980s. This was an opportunity to either change course – whether dramatically or subtly – or carry on, and the latter option was preferred.

As we have also seen, an ostensibly parallel path entered the reckoning to decisive effect. The huge yields made possible by the Green Revolution were increasingly diverted towards feeding the livestock reared by factory farming, thereby strengthening the cause of industrialisation. As a consequence, rather than saving humanity from ruin, the Green Revolution helped hasten the march towards collective annihilation.

We might reasonably infer that this direction of travel stemmed solely from the profit motive or a bent for Taylorism⁴⁸. Such an outlook would in some ways be understandable from the perspective of farmers: saddled with an abundance of crops, it was perhaps only natural that they should seek to grow their businesses and attain a better standard of living via new avenues – specifically, by feeding the industrialised machine. But this offers only a partial explanation: other drivers have been necessary for the bright hopes of the Green Revolution to somehow fade into the dismal reality of factory farming.

One of these has been a phenomenon sociologists refer to as “the normalisation of deviance”. American academic Diane Vaughan coined this term after she analysed the circumstances behind the 1986 *Challenger* space-shuttle disaster, which happened after suboptimal practices became ingrained at NASA⁴⁹. The expression can justifiably be applied to any setting in which unsustainable policies and methods are liable to lead to catastrophe – whether immediately or, in Vaughan’s words, following “a long incubation period, with early warning signs misinterpreted, ignored or missed completely”⁵⁰.

Factory farming clearly ticks these boxes. Its firmly established failings have already generated many negative impacts, and they are likely to deliver many more if left unchecked. This is undoubtedly a sphere in which the questionable has become quotidian.

The more deviance becomes normalised, the more short-termism and blinkeredness reign. NASA demonstrated as much in the run-up to *Challenger*’s accident, seeking to stifle criticism of the shuttle programme’s dwindling relevance by manipulating the agency’s concept of acceptable risk until – finally and fatefully – managers approved a launch in freezing weather conditions that were known to be perilous to the craft’s solid rocket boosters.

Analogously, factory farming persists with regimes that are known to be profoundly dangerous. The industry is aware that “business as usual” accelerates climate change and other forms of environmental damage; it is aware that more of the same threatens another pandemic; it is even aware that what it chooses to deem acceptable is in many ways the absolute opposite; yet it carries on anyway⁵¹.

And what unites the *Challenger* disaster with the tragedies in which factory farming continues to be complicit? In every instance, thanks to the normalisation of deviance, humanity has taken nature for granted; and nature, in turn, has exacted terrible revenge.

EXPERT INTERVIEW

Short-termism and the curse of “business as usual”

Christopher Wright is a Professor of Organisational Studies and leader of the Balanced Enterprise Research Network at the University of Sydney. His research explores responses to climate change, with particular reference to how managers and businesses interpret and react to the crisis.

Daniel Nyberg is a Professor of Management at the University of Newcastle, Australia. His research investigates how global and societal phenomena are translated into organisational realities, especially in relation to corporate responses to climate change.

Professors Wright and Nyberg are the co-authors of *Climate Change, Capitalism and Corporations: Processes of Creative Self-Destruction and Organising Responses to Climate Change: The Politics of Mitigation, Adaptation and Suffering*, both published by Cambridge University Press. Here they discuss how the lessons of the Green Revolution can be seen not just in modern-day agriculture but in multiple sectors and industries.

Looking back over the past three quarters of a century, what does the story of the Green Revolution tell us from the perspective of your research?

It's a story that very much reflects a challenge still faced by businesses and investors today: resolving the tension between the greater good and the profit motive. The essential tragedy is that the Green Revolution was launched with noble intentions but metamorphosed into something very different over time.

There were obviously many dynamics involved in shaping how events unfolded, and we shouldn't oversimplify things. But maybe the ultimate inference is that the original desire to serve the greater good was increasingly overshadowed by a desire to generate profits – to the point where the negative impacts might now be said to outweigh the positive impacts.

Is it possible to identify a key turning point or tipping point?

Maybe no-one could zero in on a precise moment when everything decisively changed for the worse, but it's fair to say the same general pattern or trajectory has been seen again and again in numerous business settings. Broadly speaking, it's a question of unsustainability coupled with ignorance.

What happens is that an industry or a sector, for whatever reason, reaches a stage at which its policies and practices are clearly no longer sustainable. Ideally, that's the point at which it commits to a necessary reinvention with a focus on the long term – but what usually happens instead is that it maintains a “business as usual” attitude and clings to a resolutely short-term, inherently damaging outlook.

Do you feel this sort of outlook is funnelling us towards a point of no return?

Every day we're confronted by more proof that humanity is shuffling closer to the abyss. Fundamental assumptions we once took for granted – that our weather, our climate and our ecosystem will survive us all – are collapsing before our eyes.

We have mounting evidence that prevailing policies and practices in various industries and sectors are not only unsustainable but absolutely central to most of the greatest threats facing the planet. We also have mounting evidence that long-term solutions could be achievable. But what we don't have is mounting evidence of a widespread willingness among businesses to bring about positive, lasting change.

Your research argues that businesses of all kinds routinely appear to embark on a campaign of positive change but gradually fail to embrace it – and then back away from it altogether. This especially seems to be the case in relation to environmental concerns⁵². How does this happen?

With climate change, it's usually a problem of initial promises failing to fit local production practices and how they're evaluated. This means environmental ambitions end up clashing with the profit motive, as seems to have been the case when the Green Revolution increasingly lost its way.

We've repeatedly encountered this phenomenon in how bold initial statements by CEOs and corporate leaders are gradually translated into the stuff of "core business". Environmental sustainability gets twisted into a form of what's considered financial sustainability. Basically, what you're often left with is at best greenwashing and at worst a total abrogation of corporate social responsibility.

Do investors have a duty to reform companies that lack commitment to the greater good, even assuming businesses can never truly set aside the profit motive?

We should never forget the original purpose of incorporating companies was so society could undertake necessary development. In our opinion, that means we have a duty to act responsibly and ensure the stability of the system. With that in mind, we also shouldn't forget society tends to get the businesses it deserves.

How might agricultural businesses, especially those involved in food production, serve as models for the mindset that all corporations should exhibit towards the environment and other global concerns?

We would urge them – just as we would urge businesses in any other sector – to acknowledge there have been many wrong turns over the course of several decades. We would urge them to acknowledge "business as usual" is no longer acceptable or even feasible. And we would urge them to acknowledge the lessons of recent history in particular, because these truly underline the need for positive change.

In addition, from a strictly business-oriented perspective, they should acknowledge they risk bringing about their own demise – possibly by becoming widely viewed as components of a "sin" industry. And they should acknowledge this is ultimately a question of short-term thinking versus long-term thinking – and maybe also a question of shareholder capitalism versus stakeholder capitalism⁵³.

"The industry is aware that 'business as usual' accelerates climate change and threatens another pandemic... yet it carries on anyway."

5.2 The misdirection of innovation

Another driver that has consistently steered food production away from the initial promise of the Green Revolution is the industry's use of innovation. There are two reasons why this constitutes a bitter irony.

The first is that the Green Revolution would have been impossible *without* innovation. The second is that agriculture gave us the model still widely used to describe how innovation works in any arena: the bell curve of adoption was conceived by Iowa State University researchers George Beal and Joe Bohlen in the late 1950s, when they travelled the US to deliver presentations about the farming community's recognition, acceptance and integration of novel ideas⁵⁴.

Communications theorist Everett Rogers' later refinement of Beal and Bohlen's exemplar introduced the classic distribution of innovators, early adopters, early majority, late majority and laggards⁵⁵. This has been the near-undisputed paradigm for the embracing of new technologies for almost 60 years, and the modern history of agriculture has validated it again and again; yet many of the innovations themselves have in the end served principally to maintain a status quo we now know to be entirely unsustainable.

The spread of the new crop varieties that triggered the Green Revolution perfectly mirrored the bell curve. As discussed in section 3.1, Borlaug and his fellow scientists were the innovators; the Mexicans were the early adopters; the likes of the US, India and Pakistan were the early majority; the likes of South-East Asia, Africa and the Middle East were the late majority; and the remainder were the laggards. The longer-term difficulty arose from what happened – or, more accurately, what *did not* happen – once saturation point was reached.

Unleashed by Borlaug decades previously, the forces of "creative destruction"⁵⁶ remoulded the industry – for better or worse – and subsequent developments, by and large, only reinforced existing systems. With mechanisation and factory farming marking the way ahead, incrementalism set in – further cementing the industrialised, deleterious practices already in place.

The problem persists to the present day, as shown by recent CGIAR⁵⁷ research that found only an estimated 7% of innovation spending in agriculture to be explicitly geared towards environmental outcomes. According to the study, approximately \$60 billion is invested in agricultural innovation annually in the global South – but the vast majority is focused on improving productivity and profits⁵⁸. "In a world that is rapidly undergoing climate change," said Dr PV Vara Prasad, who oversaw the analysis, "investments in innovation that fail to take environmental impacts into consideration will not change the trajectory of agriculture rapidly enough to meet sustainability and climate targets."⁵⁹

By way of illustration, take the industry's attitude to antibiotics. They were originally used to guard against or treat disease but over time became ever more focused on non-therapeutic aims, including genetic and hormonal manipulation in pursuit of boosting animals' weight and standardising their physiques⁶⁰. As FAIRR has highlighted, what began as a prudent attempt to protect the health of livestock has mutated into an irresponsible policy that encourages antimicrobial resistance and thereby seriously jeopardises animals and humans alike⁶¹. The purported enhancement of factory farming has almost invariably been the overriding consideration^{62, 63}.

This brings us to the "shark fin", a recent challenger to the dominance of the bell-curve model. An alternative framing that assumes market saturation can nowadays be accomplished almost at a stroke, it is based on a conviction that creative destruction has become so prevalent that no company, sector or industry can afford to rest on its laurels. Its proponents argue that the key to success and sustainability lies not in a "business as usual" or "job done" ethos but in having a "second act" – and a third, a fourth, a fifth and so on⁶⁴.

Today, more than 70 years after it commenced, the Green Revolution is still awaiting a genuine second act. Rather than more of the same, what is needed is a follow-up, a sequel, a meaningful progression, a new direction. Above all, what is needed is another revolution. Thankfully, as we will see in the next chapter, one is finally starting to take shape.

EXPERT INTERVIEW

The winds of change

Martin Binks was Emeritus Professor of Entrepreneurial Development at the University of Nottingham and Chair of its Haydn Green Institute for Innovation and Entrepreneurship. His areas of expertise included radical innovation thinking, technology transfer and entrepreneurship. He advised and served as a consultant to institutions including UK government ministries and the Bank of England⁶⁵.

Here he considers how innovation has shaped agriculture since the beginning of the Green Revolution and how it could now help the industry plot a sustainable future. He also highlights the crucial division between incremental innovation and its radical counterpart – and, by extension, the distinction between doing things better and doing things not only better but differently.

Was the Green Revolution worthy of its name?

I would say so, in so far as it constituted a genuine revolution at the time. It wasn't a case of piecemeal improvement. It wasn't a case of merely evolving. It was a case of identifying and meeting an unmet need, and it was genuinely disruptive.

Interestingly, this all began just a few years after Joseph Schumpeter, the great Austrian economist, introduced the idea of "the gales of creative destruction"⁶⁶. We now think of this as describing an innovation that sweeps aside what existed before, thus proving truly transformative. The gales blew with notable ferocity during the early decades of the Green Revolution. In modern-day parlance, it was a game-changer.

Did the winds die down over time?

Of course. It was inevitable. There aren't many revolutions – if any – that last forever. Einstein once said that even his general theory of relativity would eventually have to "yield to another one, for reasons which at present we do not yet surmise". The fundamental essence of scientific progress is to disprove and improve.

But it's easy for an organisation to lose sight of this truth, especially as far as radical innovation is concerned. There are various familiar justifications for disinclination, including short-termism, aversion to perceived risk and an obsession with return on investment – and all these, at least to some degree, are understandable in the face of economic, technological and political uncertainties.

Where can this sort of disinclination lead?

It can lead to nowhere. It can lead to stasis. It can even lead to oblivion. For every organisation that welcomes change there are many more that shy away from it, and what tends to happen is that they become blind to opportunity.

Backward-looking perspectives can exert an increasingly powerful grip. Many organisations are much happier to cling to the past than focus on what might lie ahead, which is why knee-jerk conservatism is still something of a default mechanism in a lot of settings.

Are there examples of the dire consequences of this mindset in other industries?

There are some classic tales of organisations that actually had the capacity to change but refused to do so. One of the most famous is Kodak, which invented the digital camera in 1975 but chose not to enter the market until 20 years later – by which time the company was so far behind the curve that it had to file for bankruptcy.

This is probably the ultimate illustration of how a focus on what's thought of as short-term certainty can lead to the very opposite – uncertainty – and even culminate in disaster. The people in charge at Kodak figured more of the same would be enough to keep carrying the business forward, and they were spectacularly mistaken.

Is agriculture in need of radical innovation?

I can't pretend to be an expert on agriculture, but I can at least say radical innovation is very often the best solution when an organisation or an industry shows itself to be unsustainable. It's the difference between settling for more of the same, as Kodak did, and finding answers to serious problems, which is what the whole world needs right now.

The key point is that incremental innovation builds on perceived certainties and aims to do things better, whereas radical innovation builds on possibilities and aims to do things not just better but differently. The emerging consensus seems to be that agriculture is one of many industries in which something different is now required.

Is it possible for an organisation or an industry to innovate its way into trouble?

I think much of human history demonstrates this beyond dispute! Almost all the major issues we face today – climate change the most obvious among them – are consequences of both the misdirection of innovation over time and a failure to continue innovating to best effect.

But it's important to recognise much of human history also demonstrates our capacity to innovate our way out of trouble. That's how we've survived as long as we have. I'm not saying it's ideal, but we keep painting ourselves into corners and somehow escaping from them. That's what the Green Revolution was all about in the first place, of course.

Can we escape this time?

Appropriately enough, this point was famously argued in the context of resource scarcity. In 1980, 12 years after he warned of societal collapse in *The Population Bomb*, Paul Ehrlich accepted a \$10,000 bet from an economist, Julian Simon, who wagered that the prices of five metals – chrome, copper, nickel, tin and tungsten – would fall during the next decade.

Ehrlich thought resource depletion would make these commodities ever more precious, sending prices up, and for a while it looked like he was right – but in the end every price instead fell, just as Simon had suggested. Why? In each instance, thanks to innovation, an alternative was identified or more plentiful supplies were unearthed. The lesson is that necessity really is the mother of invention – and it's a lesson every organisation and industry should never forget.

“Rather than more of the same, what is needed is a follow-up, a sequel, a meaningful progression, a new direction. Above all, what is needed is another revolution.”

6 The Ever-Green Revolution

6.1 Sustainability's second chance

Having examined how the Green Revolution lost its way and what this has meant for agriculture and the wider world, we now reflect on how to get back on track. In doing so, we first need to briefly revisit what was known and accepted during the Green Revolution's formative years and what is known and accepted today.

On the whole, it is clear that neither agriculture nor the wider world has irrefutably changed for the better since Borlaug first set about transforming crop production in the 1940s. It is also clear that the respective fates of agriculture and the wider world have become ever more closely interconnected. And it is clear that neither is now on a sustainable path.

Moreover, if we take into account what "green" means in the 21st century, it is clear that the Green Revolution did not translate into an *Ever-Green* Revolution. There is very little – and maybe nothing at all – green about factory farming and the role it plays in furthering ecological meltdown, ignoring animal welfare and endangering human health.

At this stage it is perhaps worth recalling the bucolic image of Borlaug learning of his Nobel Peace Prize while tending a field in the Toluca Valley. Now fast-forward to the present day and picture a stereotypical factory farm – a scene of production lines, controlled confinement, entrenched disregard for the environment, inexcusable waste and ever-present danger. How far we have come.

Should we try to wind back to 1970 or even 1950? Can we return to the turning or tipping points and endeavour to rebuild from there? Maybe, in as much as the only unforgiveable mistake is the one made twice; but it is not as simple as that. This is not a matter of merely wiping the slate clean: rather, it is a matter of understanding what has worked well, what could work better and what has not worked at all.

The Green Revolution worked well in meeting two pressing post-war objectives: enabling countries to attain self-sufficiency and staving off the likelihood of famine. With the benefit of hindsight, we now know it could have worked much better in transforming agriculture without sliding into a morass of unwelcome consequences.

We also know, again with the benefit of hindsight, that it did not work well at all in tempering the advance of intensive farming. In fact, it supported the march of industrialisation. The link between greater crop yields and a near-boundless capacity to feed factory-farmed livestock, facilitated by innovation on the demand side once abundance was reached, represents one of the most treacherous twists in this journey.

Given all the above, any hope of responsibly reorienting the quest to feed humanity must revolve around acknowledging the material risks the Green Revolution helped create. More pertinently, it must revolve around recognising, mitigating and eradicating the negative impacts agriculture still has today.

FAIRR has led the way in raising awareness of these risks and impacts. If agriculture is to grasp a second chance of achieving sustainability – and if there is to be an *Ever-Green* Revolution – the issues detailed below must inform the way forward.

“The link between greater crop yields and a near-boundless capacity to feed factory-farmed livestock is one of the most treacherous twists in this journey.”

A high-risk sector

As originally showcased in a milestone Bloomberg article⁶⁷, FAIRR first identified factory farming as a high-risk sector in 2015. In a series of trailblazing reports, including *Factory Farming: Assessing Investment Risks*, the initiative identified 28 material issues related to environmental, social and governance (ESG) considerations.

Environmental

- Air pollution
- Climate change
- Deforestation and biodiversity loss
- Disease outbreaks
- Greenhouse gas emissions
- High water use
- Natural hazards
- Poor animal welfare
- Resource scarcity
- Soil degradation
- Waste
- Water pollution
- Water scarcity

Social

- Changing consumers
- Community health impacts
- Excessive antibiotics
- Human rights
- Infectious diseases
- Land rights
- Loss of rural jobs
- Poor working conditions
- Shrinking labour pool
- Social backlash
- Social licence to operate

Governance

- Corporate governance
- Policy changes
- Sustainability disclosure
- Weak oversight

FAIRR originally outlined these considerations in tandem with a range of “killer stats investors can’t ignore”:

- Factory farming is the number-one reason for the rapid spread of bird flu (H5N2) and swine flu (H1N1). An outbreak of bird flu in the US led to \$3.3 billion in industry losses in 2015.
- Livestock as a whole, including factory farming, is responsible for 14% of global greenhouse gas emissions – more than the transport sector – with a warming climate expected to lead to a 21% rise in “heat stress” days for the cattle industry.
- Factory farming is the number-one user of antibiotics in the US, accounting for 80% of all use.
- Globally, 85% of all soya – production of which is a major cause of deforestation – is used for animal feed.
- Factory farming is the number-one consumer of water in drought-stricken California. The state’s dairies saw profits suffer a \$250 million hit due to drought in 2015.

Source: FAIRR: *Factory Farming: Assessing Investment Risks*, 2016

6.2 Cultivating a better future

Many unhappy and unforeseen corollaries have arisen from humanity's fragile relationship with or fundamental misunderstanding of nature. For example, the introduction of 120 cane toads to Australia in the mid-1930s was intended to see off a pest of beetles but instead resulted in a far-ranging trophic cascade⁶⁸; more gravely, the original goal of splitting the atom was to confirm Einstein's theory that $E=MC^2$, yet the path revealed by this landmark breakthrough eventually led to the prospect of mutually assured destruction.

The story of agriculture since the late 1940s now seems cut from much the same cloth. Humanity interfered with the natural world, and the natural world did not take kindly. We have gone from a Green Revolution to a "code red" for the planet⁶⁹. As theoretical physicist and Nobel laureate Richard Feynman once said: "Nature's imagination far surpasses our own."⁷⁰

Yet it is not too late. The fact that the industry has lost direction during the past seven decades does not mean it will require another seven to recover. Yes, we have innovated our way into trouble; but there is still time to innovate our way out of it again – provided, of course, that there is also a willingness to do so. The good news is that the seeds of the Ever-Green Revolution are already being planted, with some even sprouting and flourishing. We are seeing more signs of positive, lasting change.

Look at the rise of vegetarianism and veganism⁷¹ – especially in influential "hotspots" such as New York, Los Angeles, London and Tel Aviv⁷² – and the growing body of research showcasing their benefits, many of which have an environmental dimension⁷³. Look at trends such as Meatless Mondays and Veganuary⁷⁴. Look at the strides being made in the sphere of plant-based proteins and "clean" or "cultured" meat, which studies have indicated could free up millions of acres of pasture land for other uses and facilitate global access to a low-cost, high-protein diet⁷⁵. With one in three people in the UK deeming themselves flexitarian in 2018 and two thirds of Americans reported to have reduced their meat intake⁷⁶, it has been estimated that the global plant-based food market could soon be worth around \$100 billion⁷⁷. In tandem, those who exercise their personal choice to eat meat can move from consuming the products of industrialised agriculture to consuming the products of more responsible, sustainable, animal-welfare-centred methods of farming.

Look, too, at the leaders in the Collier FAIRR Protein Producer Index and their commitment to reshaping food production and consumption. Our research invariably shows much remains to be done, but it also shows what is being done now – particularly with regard to managing the material risks outlined in the preceding section. With more than \$5 billion invested in plant-based, cultivated and fermentation-based meat and dairy technologies, 2021 was a record year for private investment in alternative proteins⁷⁸.

There is also growing policymaker awareness of the risks associated with intensive agriculture. On 28 January 2022, for instance, the European Union (EU) enacted legislation banning the prophylactic use of antimicrobials in farming and among producers exporting meat to the EU⁷⁹, while the European Commission has pledged to phase out caged animal farming by 2027 following a public campaign to "end the cage age"⁸⁰.

Recognition of the need for agroecological and organic farming, as well as regenerative practices in the industry, has also increased in recent years. Only around 8.5% of the EU's agricultural area is farmed organically at present, but the plan is to reach 25% by 2030⁸¹ – although there also is a clear need for a "just transition" to ensure workers are not left behind by the shift to more sustainable production and to avoid the sort of unintended consequences already witnessed in countries such as Sri Lanka⁸².

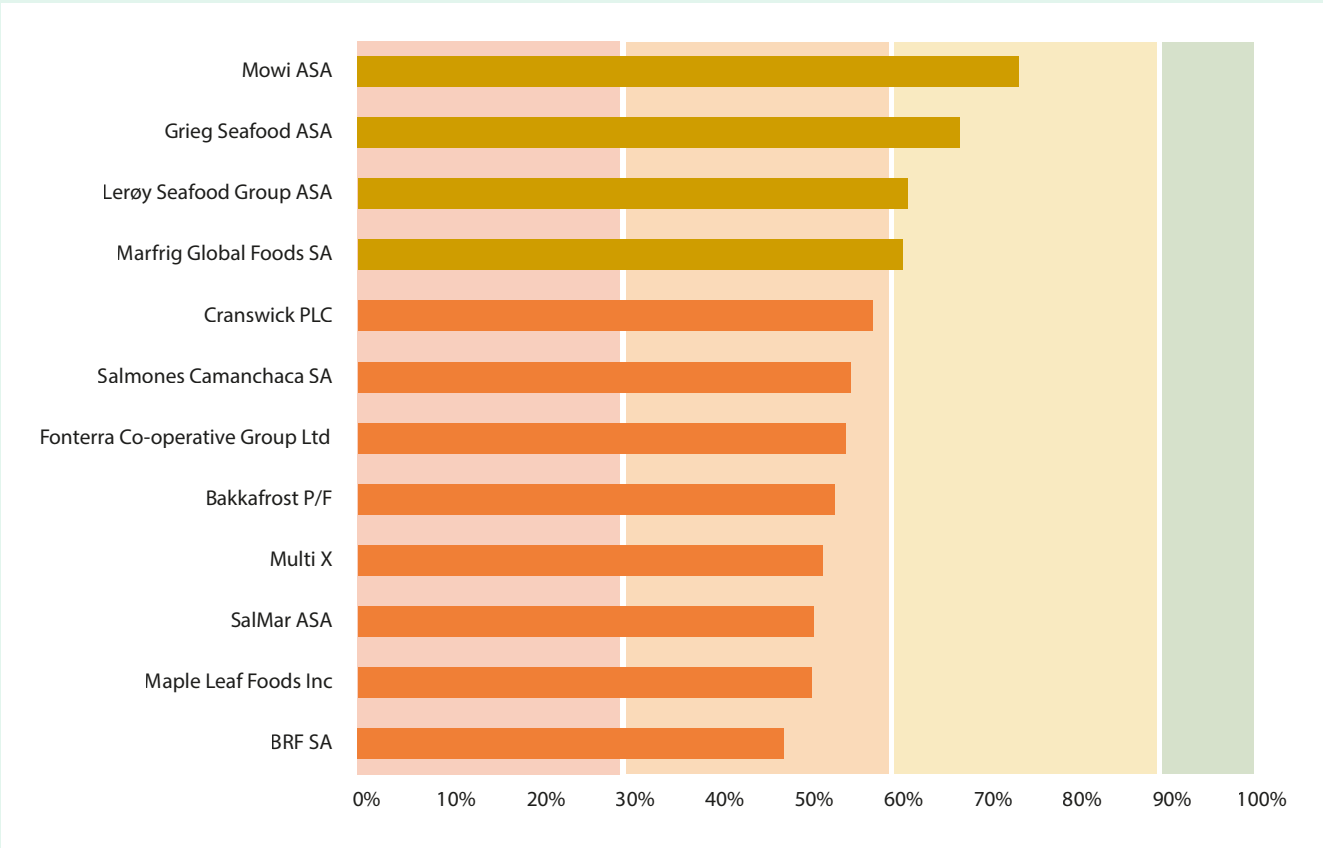
The bad news is that there are many more laggards than there are leaders – at least at present. Deviance endures. Adoption of the next wave of potentially transformative innovations has not yet crested the bell curve, let alone soared up the shark fin.

This is why the global network of investors brought together by FAIRR is using the power of active ownership to drive the industry as a whole in a more responsible, sustainable direction. Having watched the Green Revolution stray off course and fall short, we all need to play our part in cultivating a better future – one capable of realising the sort of utopia that, in the final reckoning, 70-plus years' worth of putative progress in agriculture has been unable to deliver.

The leaders of the next revolution?

The Coller FAIRR Protein Producer Index assesses the performance of companies involved in intensive farming. It focuses on 10 issues: GHG emissions; deforestation and biodiversity loss; water use and water scarcity; waste and water pollution; antibiotic stewardship; working conditions; animal welfare; food safety; governance; and sustainable proteins.

The top 12 performers in the Index’s 2022 edition are shown below. The very best are considered “low-risk” (yellow section), with the remainder deemed “medium-risk” (amber section). Although no company achieved an overall “best practice” rating (green section), half of all those assessed were found to have exposure to alternative proteins – compared to less than a quarter in 2019 and just 8% in 2018⁸³.



Source: FAIRR: Coller FAIRR Protein Producer Index, 2022

It is important to note, too, that innovation is also increasingly evident among businesses beyond the Index, particularly start-ups and SMEs investing in sustainable food production. Below we briefly outline five areas of innovation that are helping cultivate the next revolution in agriculture.

Plant-based pioneers

Plant-based meats are proteins produced directly from plant sources. While traditional examples include tofu, tempeh and seitan, a cutting-edge “biomimicry” approach has enabled companies such as Beyond Meat and Impossible Foods to create products that imitate the appearance, taste, smell, texture and even the chewiness of meat.

The health benefits of plant-based foods are helping reshape consumer demand. The Good Food Institute reported sales in this sector grew twice as quickly as those for food products overall in 2020, with two-year growth of 43%⁸⁴; more growth has followed⁸⁵.

The environmental dimension is also key. For example, research has suggested switching from conventional beefburgers to Beyond Meat’s Impossible Burger would equate to an 89% reduction in greenhouse gas emissions⁸⁶, while Dr Joseph Poore, lead author of a 2018 study of the environmental damage caused by approximately 40,000 farms in 119 countries, has claimed: “A vegan diet is probably the single biggest way to reduce your impact on planet Earth.”^{87, 88}

Clean meat

Clean meat – also known as cultivated or lab-grown meat – is animal protein produced by culturing animal cells in a laboratory and then using a bioreactor to replicate the tissue structure of meat.

These products offer a genuine animal protein source. Crucially, it is one that does not require the slaughter of animals or the use of antibiotics and which emits fewer greenhouse gases and uses less water and land.

A FAIRR analysis showed lab-grown meat attracted record levels of investment in 2020, growing sixfold and reaching \$366 million. This total was itself far exceeded in the first half of 2021, with investment standing at \$506 million⁸⁹. However, as discussed below, another technology – fermentation – has since attracted greater attention.

Fermentation

The market for alternative proteins is generally viewed as consisting of three components, the first two of which – proteins derived from plants and proteins produced by culturing animal cells – we have already discussed above. The third is fermentation, an area in which technological advances are unfolding at pace.

Fermentation can itself be divided into three types. Traditional fermentation – as used, for example, to produce cheese and wine – uses microbial anaerobic digestion, mainly to improve the function or flavour of alternative proteins. Biomass fermentation – as used, for example, by meat substitute company Quorn to grow fungi – uses microorganisms with high protein content and rapid reproduction capabilities to produce protein in large volumes. Precision fermentation – as used, for example, to produce insulin for diabetics – uses microorganisms to produce specific ingredients, including proteins, enzymes, flavour molecules, vitamins, pigments and fats.

The most advanced precision fermentation processes now encompass synthetic biology, DNA sequencing and recombinant protein technology. These methods are especially to the fore in the production of animal-free milk protein, as showcased by alternative dairy pioneers such as Perfect Day⁹⁰; Impossible Burger’s R&D team also used such techniques to synthesise soy leghaemoglobin after identifying it as a plant-based source of red colour and meaty flavour⁹¹. As a result, precision fermentation is now increasingly thought capable of uniting all three strands of the alternative protein industry – either by producing standalone protein sources or as an additive technology that can provide ingredients and enablers to the plant-based and cultivated meat industries⁹². Private investments in fermentation-enabled food technologies reached \$1.5 billion in 2021 – up 147% on 2020 – and \$290 million in the first quarter of 2022 alone⁹³.

Sustainable feed

Perhaps no aspect of food production is as volatile or as vulnerable today as feed. This is why some animal protein producers are turning their attention to developing sustainable feed options.

The 2021 edition of the Collier FAIRR Protein Producer Index identified nine meat, fish and dairy firms investing in alternative feed ingredients. Among these businesses is Cranswick, a UK-based pork and poultry producer, which is trialling insect protein and protein-rich crops such as peas and beans.

The global salmon-farming industry is also under pressure to find affordable, enduring feed solutions – both because of rising costs and in light of the rapid depletion of wild fish stocks. The Millennial Salmon Project is exploring two possibilities – insect-based feed and algae-based omega-3s – thought capable of enhancing sustainability in this sector⁹⁴.

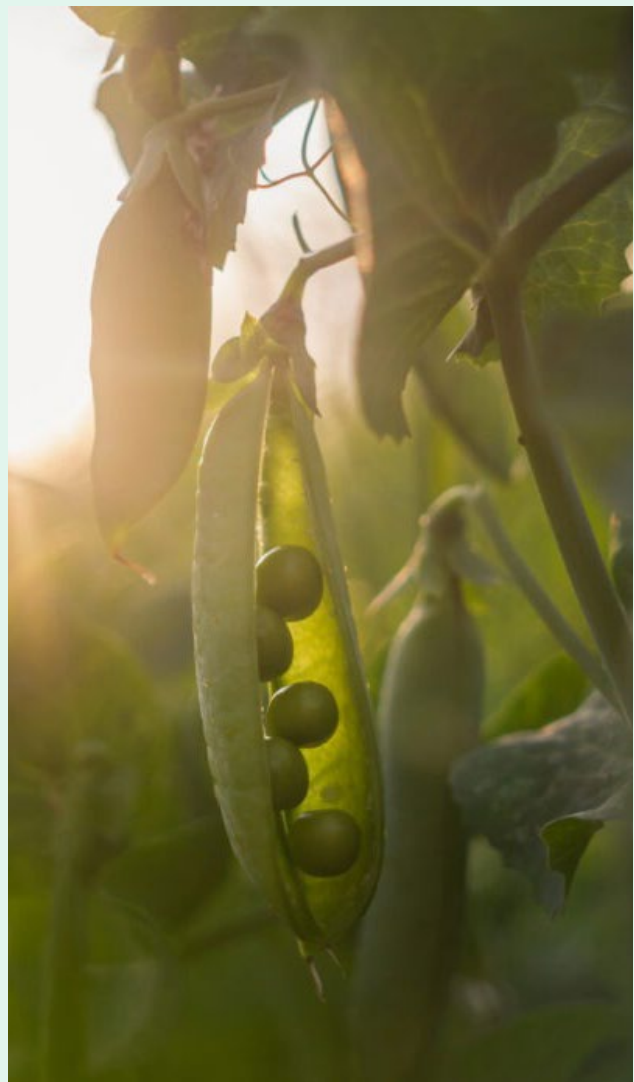
Net-zero farming

Many farmers in the UK are already working with the National Farmers Union (NFU) to develop net-zero farms. This involves embracing new technologies in areas such as carbon storage, renewables and bioenergy.

Innovations including rooftop solar photovoltaics, biomethane anaerobic digestion, biomass heating, state-of-the-art ventilation systems and LED lighting are all contributing to the desired shift. The NFU's overall goal is to achieve net zero across the whole of agriculture in England and Wales by 2040⁹⁵.

Through CO₂ capture, good woodland management and precise tree-planting can also help reduce farms' emissions. A consistent programme of planting is now recognised as highly beneficial in promoting continuity in carbon storage.

“The seeds of the Ever-Green Revolution are already being planted, with some even sprouting and flourishing. We are seeing more signs of positive, lasting change.”



7 EXPERT INTERVIEW

Final thoughts: hope for the future

7.1 The tools for utopia

In this section, which is presented in the form of a Q&A, **Jeremy Coller** reflects further on some of the issues explored in this paper. These include the importance of focusing on causes rather than symptoms when confronting the challenges to which the traditional food system has helped give rise; the power of ownership in driving change; and the trailblazing work of FAIRR in reforming longstanding policies and practices.

Jeremy also discusses the idea of the Green Revolution's initial success engineering its ultimate failure. In addition, he explains why factory farming is likely to become a stranded asset for investors and why he believes an *Ever-Green* Revolution is now both under way and achievable.

Is it fair to describe the Green Revolution as a failure?

Yes, but it's vital to acknowledge the extremely unusual circumstances behind its failure. The fact is that it failed because it was too successful. It succeeded in creating an abundance, but it failed because of how that abundance was used.

Relatedly, it's also important to note every revolution is launched in the hope it will last. That doesn't necessarily mean it will prove absolutely immutable and nothing will ever change again, but the assumption tends to be that it will at least remain at the heart of whatever follows.

The Green Revolution has certainly failed in that regard, for the simple reason that it completely lost its way over time. It represented a remarkable breakthrough and brought a lot of positive change over the short-to-medium term, but its long-term impact, frankly, has been disastrous – which is why we now need to start from scratch.

Do you think the path it took was entirely unintended?

I think it was unintended by the revolution's original architects. I don't believe Norman Borlaug or the Rockefeller Foundation – which made his work possible⁹⁶ – ever envisioned a world in which an abundance of cereals would be used to feed factory-farmed animals rather than the human population.

But I think there came a point when the decisive shift – from using that abundance to feed people to using it to feed animals – became all too deliberate. I would say the channelling of that glut into the growth of industrialised farming was very much by design. And a further revolution, the discovery of antibiotics, also fuelled the shift.

And in a way, of course, that intention can be thought of as quite understandable. If you were a farmer back then, having seen your profits collapse because of an overabundance of supply, why wouldn't you support a new source of growth? It would have been perfectly natural to follow whichever route could allow you to prosper and enjoy a better standard of living.

Does this mean the farmers were selfish? Not necessarily. It would have been pretty amazing if one any of them had stepped back and declared: "Hold on – I'm not sure this approach will serve the greater good in the fullness of time."

Does it mean they were greedy? That's much more likely. Anyone who has studied philosophy will know the question of whether we're born immoral has been debated for centuries. I happen to think humans, both individually and as a species, are *innately* greedy – and that's a trait we'll need to overcome if we're sincerely committed to building a better world.

Other than a desire for personal growth and prosperity, what do you see as the key reasons for the revolution losing its way?

There have been numerous factors over the course of several decades. Together, they've ensured not only that the revolution petered out but that an unsustainable status quo emerged.

One factor has been a focus on innovation on the demand side. As we've explained in this paper, what has passed for progress – and I use the term loosely – has served principally to prop up and even strengthen the industrialised model.

Another is what I call the phony framing of the middle class. The notion that eating meat indicates upward social mobility has underpinned increased demand for protein, which in turn has driven the spread of factory farming.

It's important to stress at this point that I don't believe eating meat should be outlawed. That's not my view at all. I'm a vegan now and was a vegetarian from the age of 12, but I fully understand this is a question of personal choice. We're not going to transform the food system by ordering everyone to eat spinach and lentils. We can't just tell people: "Eating burgers is now banned." Consumers have to be given what they want.

I do think, though, that we need to get away from the idea that eating meat is an indisputable sign of economic and societal advancement. That's simply not true in the 21st century, and it's a misrepresentation that serves only to prolong factory farming's pre-eminence.

I also believe government subsidies have perpetuated the industrialised model. Subsidies should be geared towards creating a new and truly sustainable system of food production, not towards preserving an old system that we already know isn't fit for purpose anymore.

Could governments have done more in the past? And could they do more now?

Yes, but we shouldn't fall into the trap of viewing more regulation and legislation as a miracle cure-all. There's an issue known as "the pacing problem", which comes about when innovation – even the *wrong* kind of innovation – totally outstrips regulatory and legislative attempts to keep up with it⁹⁷.

Even if governments could somehow keep pace with how an industry or sector develops, it's highly unlikely that they could ensure positive change on their own. That's where the investment community and the power of ownership enter the picture – especially today, when we're able to look at the business world through the lens of ESG.

Ultimately, the vital question is this: who owns these companies? Who actually owns the businesses that constitute our food system? The answer in most cases is that citizens own them – they own them through their investments.

This is particularly the case with pension funds. Prior to 1950, when General Motors established the first "modern" pension fund⁹⁸, these institutions had virtually no say in how businesses were run. Today they hold tens of trillions of dollars' worth of assets worldwide⁹⁹ and can exert an enormous influence on the companies in which they invest.

They're now routinely exerting that influence through an ESG lens. They're asking: "What's the point of having a pension in 2050 if the climate's going to be so damaged that no-one can go outside?" They're asking: "Why should we plough our money into a food system that's going to ruin the world before we even get to retirement age?"

These citizens, these institutions, also want to protect their investments from risk. ESG provides a means of doing that, too.

If a company is going to construct a textile factory, for example, then investors might reasonably insist the building has fire exits and solid foundations. They would do this not just because they care about the employees and "doing the right thing", which is basically a matter of corporate social responsibility, but because they understand it's simply good business. From an investor perspective, managing the material financial risks a company faces preserves the long-term value of portfolios – and that's what ESG promotes.

Can you give an example of this kind of investment ethos in action in the food sector?

Consider how a restaurant chain deals with the use of antibiotics in the food supply chain. That's very much a question of risk and good business. It was actually the subject of the first engagement FAIRR ever undertook, back in 2016.

We asked 20 major restaurant chains – including McDonald's, Wendy's, Burger King and KFC – about their antibiotics policies¹⁰⁰. Only one had any sort of policy at the time, but they all had one by the end of 2019.

And that's the beauty of our position. We're not a government or even an NGO. We're the owners of these companies, and we have a powerful voice. Through the lens of ESG, we can encourage sustainability, reduce risks and seek to optimise profit from the perspective of materiality rather than morality.

What if businesses choose to ignore this voice, regardless of how powerful it might be?

They won't survive. We've already seen instances of companies that were once big players in the food sector being left behind because of their failure or refusal to adapt.

For example, it's more than a decade since Westland-Hallmark, one of the largest meat-processing companies in the US, entered bankruptcy after secret footage of animal abuse sparked a multi-million-dollar recall of its products¹⁰¹. Two of the US's biggest traditional dairy producers, Borden and Dean Foods, went bust in rapid succession a couple of years ago in the face of competition from alternative products¹⁰².

Eventually, we're going to see factory farming as a whole become a stranded asset. Everything is against it. Even the path to net zero leads to the doors of the world's largest meat, fish and dairy companies. As I've said before, cows are the new coal.

So what needs to happen in order for an Ever-Green Revolution to succeed?

The first thing that needs to happen is what we've aimed for in this paper, which is a root cause analysis of so many of the most pressing problems we're facing today. There's a huge amount of attention focused on the symptoms, but we need to be clear about the causes.

There's no doubt that factory farming is a leading contributor to climate change, deforestation, pandemics and other crises. So the optimum solution isn't to try to deal with these crises as they occur, as if we're desperately fighting wildfires that suddenly spring up here, there and everywhere. The optimum solution is to end factory farming.

And we're now actually in a position to do that. We have the tools to create the utopia that the original Green Revolution failed to produce.

The most important of those tools is technology. The age of agtech and foodtech – agricultural technology and food technology – is already under way. Look at countries such as Israel and the United Arab Emirates, which have invested heavily in this tech in recent years, and you'll get an idea of the amazing transformation that's possible.

There's a powerful causal linkage at play here, just as there was between the Green Revolution and factory farming. But in this case the linkage is reversed.

There couldn't have been factory farming without the Green Revolution. Now there can't be an Ever-Green revolution without agtech and foodtech.

Another key point is that we're seeing more joined-up thinking from governments and investors. That's also a feature of the countries that have been ahead of this curve. Supranational organisations such as the United Nations and the World Bank are also increasingly recognising what's at stake, what needs to be done and what's now actually achievable.

And will this revolution, unlike its predecessor, be one that lasts?

Yes, I'm extremely confident about that. As long as we avoid the errors of the past, genuine sustainability is well within our grasp.

The biggest error of all as far as the Green Revolution was concerned was to feed billions of factory-farmed animals. We should have instead fed billions of animals of another kind – namely, humans.

Just pause for a minute and imagine how many humans could be fed with all the produce that feeds almost 80 billion factory-farmed animals every year. Any figure would be speculative, of course, but we can at least bear in mind that only around half of the crops grown today are used to feed people directly¹⁰³ – and more than three quarters of farmland globally is given over to livestock¹⁰⁴. We're undoubtedly talking about a capacity to feed billions more people.

To that extent, although the challenges we face can be presented as highly complex¹⁰⁵, the solution here is simple: we just need to feed humanity with much more of the food we're able to produce. Factory farming has been an obstacle rather than an enabler in that respect, because it has consumed an abundance that might otherwise have been used to help end hunger and undernourishment around the world.

Another of the most unfortunate consequences of the Green Revolution's initial success was a culture of short-termism, with every stakeholder group happy to act in its own interests. Businesses and farmers saw an opportunity to profit. Policymakers saw an opportunity to augment what they defined as the middle class. Lobbyists saw an opportunity to strengthen the food industry's position. Investors saw an opportunity to earn quick returns.

The Ever-Green Revolution has to be true to its name, which means it has to be about the long term. I believe it will last because tech will continue to provide more and better solutions. It will last because of the wider appetite for change, especially among younger generations. It will last because it will deliver a just transition for everyone, including farmers and those who choose to eat meat. Maybe above all, it will last because there's simply no viable alternative. It really is in our hands.

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“Eventually, we’re going to see factory farming as a whole become a stranded asset. Everything is against it. As I’ve said before, cows are the new coal.”

What next for farmers?

The Green Revolution and the rise of factory farming continued a story of wildly fluctuating fortunes for many farmers during the 20th century. The principal ups and downs, in this case as experienced by farmers in the US, are outlined below. A key goal of the *Ever-Green Revolution* must be to deliver a just transition for farmers and thus ensure this century is less tumultuous than its predecessor.

1900 – 1920

War lays waste to much of farming in Europe, creating a boom market for US farmers

Result: oversupply and investment

1920 – 1940

Prices fall to pre-war levels, leaving farmers who borrowed to cash in on the boom unable to pay their debts; the Great Depression and the Dust Bowl drought further devastate rural communities

Result: poverty farming

1940 – 1960

The Green Revolution introduces new crops and methods, rapidly transforming the US agriculture industry from net importer to net exporter

Result: abundance

1960 – 1980

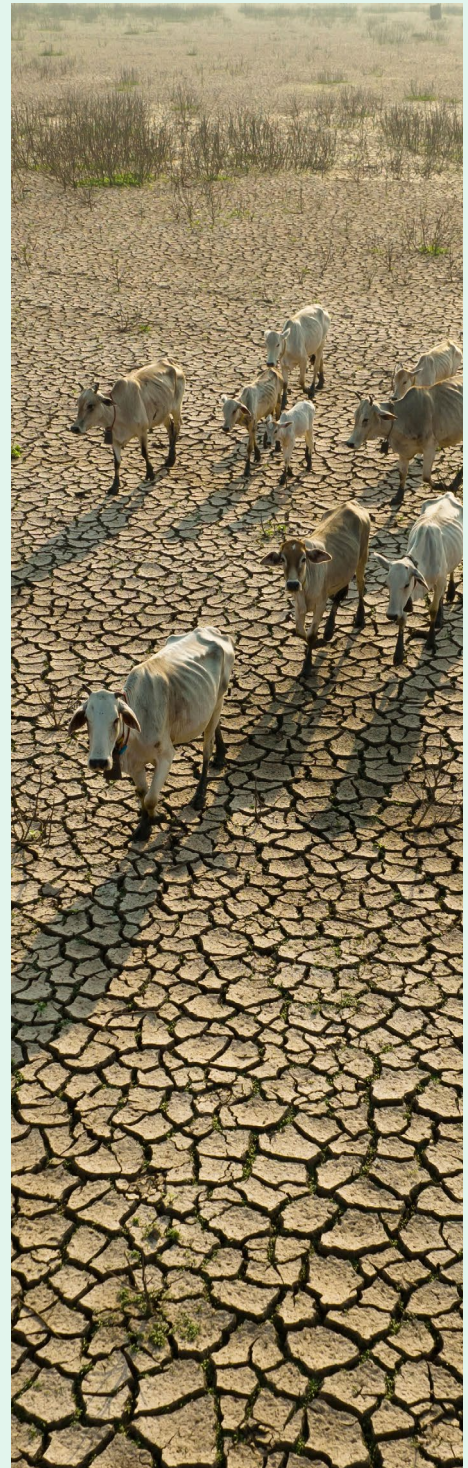
The continued rise of factory farming and the consequent demand for animal feed presents new opportunities for struggling farmers

Result: commodity farming

1980 – present day

Factory farming cements and maintains its dominance, exacerbating environmental decline and other global challenges

Result: unsustainable farming



7.2 Conclusion

We began this paper by posing a hypothetical question: what if the Green Revolution had achieved only what it set out to accomplish? We conceded from the outset that there could be no definitive answer, but we also said it should be possible to determine what has been good or bad about the longer-term development of agriculture since the middle of the 20th century.

We have explored how we arrived at where we are today. We accept that the Green Revolution commenced out of necessity and with good intentions and that it likely saved an enormous number of lives; but we believe it gradually lost its way in light of both factory farming's rise and, with cruel irony, the revolution's own capacity to sustain that rise. With an abundance that might have fed humanity instead diverted to feeding nearly 80 billion animals, we suggest the unintended consequences – over time and on balance – have outweighed the envisaged benefits.

What could have happened if the Green Revolution had not taken place at all or if it had unfolded differently is more difficult to say. Hindsight is one thing; speculation is another altogether. Yet we can at least offer some very broad scenarios. Assuming other innovations failed to fill the void, famine could have brought death and devastation. Assuming other innovations did fill the void – and assuming, too, that they proved more sustainable – the world may have looked very different today. We will never know for certain, but we might have been much closer to a utopia than we are now.

This brings us to the challenge of reorienting the course of food production and ensuring sustainability for the agricultural industry and its myriad stakeholders. Has the chance of utopia gone forever? The mindset required in contemplating the task that now confronts us is neatly encapsulated in the following quote:

“Civilisation as it is known today could not have evolved – nor can it survive – without an adequate food supply. Yet food is something that is taken for granted... Many insist on ignoring the lessons available from history.”

These were the opening lines from Norman Borlaug's Nobel Lecture in 1970, since which time history has delivered many more lessons – most of them harsh. As remarked earlier, food security was one of a comparative handful of existential threats when Borlaug embarked on his research. Today we face multiple crises, most of which have been exacerbated – if not in part created – by what were once seen as solutions.

How we produce and consume food is now the main driver of the ecological and climate catastrophes pushing nature beyond what is deemed a safe operating space for humanity. Four of the nine planetary boundaries that define the Earth's biological and physical systems have already been transgressed¹⁰⁷. The World Wide Fund for Nature has warned we have to “consume and produce food differently... for people and nature to thrive”¹⁰⁸. The Intergovernmental Panel on Climate Change has urged the industry to adopt “sustainable production systems”¹⁰⁹. A major scientific analysis of food shocks has called for “bold food policy”¹¹⁰. One study has even suggested the hidden costs generated by the food sector – for example, environmental damage and disease – exceed the market value of the entire food system¹¹¹.

The first step in a new bid for genuine sustainability must therefore be an acknowledgement that many of the practices still widely favoured in agriculture today are not future-proof. In fact, they are the very opposite: they place the future in grave doubt. This is why a culture of “business is usual” is not an option and total, positive transformation should be the principal goal. The Food and Agriculture Organisation's planned “roadmap” should represent a new landmark in outlining the necessary shift, and FAIRR is proud to have spearheaded the successful campaign for action in this regard.

Amid fast-mounting evidence of the urgent need for change, the status quo cannot go on. Looking ahead, we must do everything in our collective power to protect the ecosystems on which we rely for our own survival. Just as Borlaug's “miracle” crops once did, the momentum for another revolution – an Ever-Green Revolution – is growing rapidly.

Crucially, as stated in the introduction to this paper, we have the means of delivering this revolution in our own hands. The key to feeding humanity lies in ending factory farming this is a truth that can no longer be ignored. The way forward is not only obvious, it is less arduous and less complicated than has long been assumed. With agtech and foodtech redefining what is possible, we can end the blight of factory farming and propel food and agriculture into a new era that will change the world and benefit billions of lives. This time, finally, we can get it right.

The day the conversation began to change

FAIRR started drawing attention to the risks around factory farming in 2015. In December that year, in the Bloomberg article reproduced below, the initiative made a major breakthrough in generating mainstream awareness of the need to rethink – and, through investment, reshape – long-established agricultural policies and practices. Today FAIRR's membership is responsible for around \$70 trillion in assets under management globally.

An investor presses his case against industrial-scale farming

Environmental and animal-rights groups have spent decades arguing against large-scale, intensive livestock facilities, arguing that these so-called factory farms are bad for the environment, farm animals, and human health. A private equity investor is taking a different approach to the same fight.

Jeremy Collier, who founded London's Collier Capital, is warning investors that ignoring animal welfare and other risks associated with industrial livestock farms can be bad for their bottom line. He created the Farm Animal Investment Risk & Return Initiative to create a network of like-minded investors who consider animal welfare and other factory farm issues in their decisions. Collier, a vegetarian, said the effort is "about materiality", not morality. "It's about being a bad investment risk."

Collier has just released a 31-page report that includes "killer stats investors can't ignore" about intensive livestock farming. The report doesn't single out companies for investors to avoid. Instead, he outlines more than two dozen environment, social and governance issues related to industrial livestock farming that he says pose financial risk. For instance, the report notes that livestock produce greenhouse gases that contribute to climate change, threaten human health by creating antibiotic resistant bacteria and consume vast natural resources, such as land and water.

Consumers, companies and regulators are already making changes to the market, leading to reductions in reducing antibiotic use and the phasing out of gestation crates for sows and battery cages for hens. But he believes investors have been slower to consider the consequences of factory-style farming as part of a responsible investment strategy. "There is a

huge knowledge gap for investors," Collier says. "What we are trying to do is start this network to fill this knowledge gap."

The report, released Wednesday, comes in the midst of a vigorous debate about how to feed a growing population despite diminishing natural resources. American livestock farmers produce relatively cheap and abundant meat and dairy products on industrial-style farms, and those methods are being exported to developing nations, particularly in Asia, to meet increased demand for animal protein. But some scientists warn that the trend is unsustainable.

While profits at many agribusiness giants – including meatpackers Tyson Foods and JBS – remain robust, Collier's report cites several examples of the economic perils of industrial livestock production. The 2008 animal welfare scandal at California-based Hallmark/Westland Meat company, in one high-profile example, led to the biggest meat recall in US history and an eventual bankruptcy.

Abigail Herron, head of responsible investment engagement at Aviva Investors, which signed on to Collier's initiative, says her firm uses animal-welfare practices as a proxy for a company's governance. If a company is behind the times on animal welfare, she says, it raises concerns about what other areas might be lagging. "Companies that address these issues better will perform better," Herron says.

Collier suggests agribusiness and food companies that ignore animal welfare and environmental concerns will become "the new coal", losing their lustre with investors as the risks become more apparent. His report cites the "tasty financial results" for companies that embrace his worldview, including Hampton Creek, the maker of egg-free Just Mayo, and Chipotle Mexican Grill, the fast-food chain that highlights its commitment to animal welfare. But even those investments aren't risk-free.

The recent E. coli outbreak at Chipotle has sickened dozens of people and caused its high-flying stock to plummet – but that hasn't moved Collier from his support of their practices. "E.coli is a food safety issue rather than a farm animal welfare issue and could happen to any company," Collier said.

Bloomberg: "An investor presses his case against industrial-scale farming", 10 December 2015

A perspective view of a long, modern greenhouse. On the right side, there are rows of tomato plants growing in raised beds, with many green and some red tomatoes visible. On the left side, there is a long, straight concrete walkway with a white metal railing. The greenhouse has a high, arched ceiling with a complex network of white structural beams and translucent panels that let in natural light. The overall atmosphere is clean and industrial, yet filled with life from the plants.

*“With agtech and foodtech
redefining what is possible,
we can end the blight of
factory farming and propel
food and agriculture into a
new era that will change the
world and benefit billions
of lives.”*

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Endnotes

- 1 According to numerous respected sources, this is the global population at the time of writing. See, for example, United Nations: "Day of eight billion", November 2022.
- 2 See, for example, Reuters: "COP27: UN food agency plan on farming emissions to launch by next year after investor push", 10 November 2022.
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- 4 Much of the first half of the 20th century was especially tumultuous for agriculture in the US. Many farmers found themselves in a position of oversupply during World War I, when farming in Europe was devastated and the US government guaranteed prices for farm products to supply the army; but demand dried up with the advent of the Great Depression, and the severe Dust Bowl drought of 1933 – as famously depicted in John Steinbeck's *The Grapes of Wrath* – saw wheat prices double and condemned huge numbers of rural families to reliance on emergency government relief. US economic output as a whole did not recover to pre-1929 levels until World War II. See, for example, University of Cambridge: "Agricultural markets and the Great Depression: lessons from the past", 7 May 2014; and Steinbeck, J: *The Grapes of Wrath*, 1939. See also section 7.1.
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- 6 As early as 1954, building on an idea first promoted by Democrat Senator Hubert Humphrey, the US created the Office of Food for Peace. President Dwight D Eisenhower described the initiative as "the basis for a permanent expansion of our exports of agricultural products, with lasting benefits for ourselves and peoples of other lands". A key aim was to make maximum use of surplus agricultural commodities while at the same time furthering US foreign policy by assisting food-deficient, cash-poor nations. Critics labelled the move "a means of disposing of costly domestic agricultural surpluses". See, for example, Rietkerk, A: *The Constructive Use of Abundance: the UN World Food Programme and the Evolution of the International Food-Aid System During the Post-War Decades*, 2015; and Bovard, J: *The Continuing Failure of Foreign Aid*, 1986.
- 7 See Nobel Prize: "Norman Borlaug – Nobel Lecture: The Green Revolution, Peace and Humanity", 1970.
- 8 See, for example, Intergovernmental Panel on Climate Change: *Special Report on Climate Change and Land*, 2019. The report noted use of nitrogen fertilisers had increased by around 800% since 1961, with use of water resources for irrigation rising by more than 100% during the same period.
- 9 In India, for example, approximately 30,000 varieties of rice were grown prior to the Green Revolution. Today there are around 10.
- 10 See, for example, United Nations Environment Programme: "10 things you should know about industrial farming", 2020; and World Health Organisation: "Food safety: pesticide residue", 2016.
- 11 See, for example, Food and Agriculture Organisation: *The Future of Food and Agriculture: Trends and Challenges*, 2017.
- 12 Of course, the quest to eliminate hunger relies on more than successful innovation in agriculture. Politics is also likely to prove vital, as economist Amartya Sen has repeatedly argued in suggesting a link between democratic freedoms and an absence of famine. See, for example, Sen, A: *Development as Freedom*, 1999.
- 13 As we explain later in this paper, this conviction holds true only if the abundance of produce made possible by the Green Revolution continues to be used mainly to feed livestock rather than to feed humans. Factory farming has created its own Malthusian effect in this regard.
- 14 See, for example, Global Hunger Index: *2021 Global Hunger Index: Hunger and Food Systems in Conflict Settings*, 2021. India, one of the Green Revolution's poster children, ranked 101st out of 116 countries surveyed.
- 15 See Food and Agriculture Organisation: *The Future of Food and Agriculture: Trends and Challenges*, 2017. The report observed: "Persistent and widespread hunger and malnutrition remain a huge challenge in many parts of the world. The current rate of progress will not be enough to eradicate hunger by 2030 and not even by 2050."
- 16 See, for example, World Bank: *Awakening Africa's Sleeping Giant: Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond*, 2009.
- 17 See, for example, Shiva, V: *The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics*, 1991; Harwood, J: *Was the Green Revolution Intended to Maximise Food Production?*, 2019; and *Guardian*: "Norman Borlaug: agricultural scientist who averted famine with a controversial 'Green Revolution'", 13 September 2009.
- 18 See, for example, Food and Agriculture Organisation: *The Future of Food and Agriculture: Trends and Challenges*, 2017.
- 19 See United Nations Environment Programme: "10 things you should know about industrial farming", 2020.
- 20 The 2022 assessment reported 44 countries with "serious" or "alarming" levels of hunger. See, for example, *Global Hunger Index: 2022 Global Hunger Index: Food Systems Transformation and Local Governance*, 2022.
- 21 See Ehrlich, P: *The Population Bomb*, 1968. Ehrlich went on to become a high-profile prophet of doom, making frequent media appearances. "Sometime in the next 15 years," he said during one interview on US television, "the end will come. And by 'the end' I mean an utter breakdown of the capacity of the planet to support humanity." See also *Smithsonian Magazine*: "The book that incited a worldwide fear of overpopulation", January/February 2018.
- 22 See, for example, United Nations: *2019 Revision of World Population Prospects*, 2019.
- 23 See, for example, Food and Agriculture Organisation: *How to Feed the World in 2050*, 2009; World Health Organisation: "2014 revision of the World Urbanisation Prospects", 10 July 2014; and Food and Agriculture Organisation: *The Future of Food and Agriculture: Trends and Challenges*, 2017.
- 24 See, for example, United Nations Environment Programme: *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission*, 2020.
- 25 See, for example, *Our World in Data*: "Meat and dairy production", November 2019.
- 26 See, for example, United Nations Environment Programme: *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission*, 2020.
- 27 See, for example, American Society for the Prevention of Cruelty to Animals: "Animals on factory farms", 2021; World Animal Protection: "The myth of UK farming", 2021; Sentience Institute: "US factory farming estimates", 11 April 2019; and FAIRR: *Factory Farming: Assessing Investment Risks*, 2016.
- 28 See, for example, Grandin, T: *Evaluation of the Welfare of Cattle Housed in Outdoor Feedlot Pens*, 2016.
- 29 See, for example, Reuters: "Flush with cash, Chinese hog producer builds world's largest pig farm", 7 December 2020.
- 30 See, for example, *Eating Better*: "Half a million chickens on one farm – is this really agriculture?", 12 May 2021.

- 31 This view – which can be seen as increasingly outdated – continues to be advanced by policymakers, academics and, above all, the meat industry. See, for example, World Bank: “Moving towards sustainability: the livestock sector and the World Bank”, 22 February 2022; Whitton, C, Bogueva, D, Marinova, D. and Phillips, C: *Are We Approaching Peak Meat Consumption? Analysis of Meat Consumption from 2000 to 2019 in 35 Countries and Its Relationship to Gross Domestic Product*, 2021; and Beef Central: “World’s growing middle class has big implications for beef”, 17 October 2018.
- 32 See Food and Agriculture Organisation: *Mapping Supply and Demand for Animal-Source Foods to 2030*, 2011.
- 33 Borlaug used his Nobel Lecture to highlight the power of “agricultural research and education” in helping “to sustain and humanise life”. See Nobel Prize: “Norman Borlaug – Nobel Lecture: The Green Revolution, Peace and Humanity”, 1970.
- 34 See Food and Agriculture Organisation: *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*, 2013.
- 35 See, for example, *Forbes*: “Move over, PETA: meat companies have a new thorn in their side”, 7 April 2019.
- 36 See FAIRR: *Coller FAIRR Protein Producer Index*, 2020. Both the 2021 and 2022 editions noted improvement, although the latter observed: “It is still not unusual to see companies backsliding on their targets.”
- 37 See, for example, *Nature*: “Global forest survey finds trillions of trees”, 2 September 2015.
- 38 See, for example, Dalin, C, Wada, Y, Kastner, T, and Puma, M: *Groundwater Depletion Embedded in International Food Trade*, 2017.
- 39 See, for example, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: *Global Assessment Report on Biodiversity and Ecosystem Services*, 2019.
- 40 Ibid. Launching the report, Sir Robert Watson, Chair of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, warned: “We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide.”
- 41 See, for example, S&P Global Market Intelligence: “How is agriculture impacted by ESG investing?”, 24 February 2020; and United Nations Environment Programme: “10 things you should know about industrial farming”, 2020.
- 42 We return to this issue in section 5.2.
- 43 See, for example, Dignard, C, and Leibler, J: *Recent Research on Occupational Animal Exposures and Health Risks: A Narrative Review*, 2019.
- 44 See, for example, World Health Organisation: *Antimicrobial Resistance: Global Report on Surveillance*, 2014.
- 45 See, for example, Food and Agriculture Organisation: “Polluting our soils is polluting our future”, 2 May 2018.
- 46 See FAIRR: *An Industry Infected*, 2020. The report warned: “Factory farming is both vulnerable to pandemics and guilty of creating them. It is a self-sabotaging cycle that destroys value and risks lives.” See also FAIRR: *Industry Reinfected*, 2022.
- 47 See, for example, World Economic Forum: *The Global Risks Report 2020*, 2020.
- 48 Frederick Winslow Taylor was one of the first management gurus and the prototypical advocate of industrial efficiency. He summarised his ideas in *The Principles of Scientific Management*, published in 1911, but some academics have suggested many of the attributes that now define factory farming – for instance, speed, scale and monotony – can actually be traced back to the pre-Taylor era. See, for example, *Guardian*: “COVID-19 shows factory food production is dangerous for animals and humans alike”, 8 September 2020.
- 49 See Vaughan, D: *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA*, 2016.
- 50 Ibid.
- 51 The fundamental reason for such a “business as usual” approach, of course, is likely to be profit. Within agriculture, as discussed in more detail in section 7.1, government subsidies are often key in this respect.
- 52 See, for example, Nyberg, D, and Wright, C: *Climate-Proofing Management Research*, 2020.
- 53 As discussed in more detail in section 7.1, these issues are of particular significance in the age of environmental, social and governance (ESG) considerations.
- 54 See Beal, G, and Bohlen, J: *The Diffusion Process*, 1957.
- 55 See Rogers, E: *Diffusion of Innovations*, 1962.
- 56 Coined by Austrian economist Joseph Schumpeter, this term is used to describe the impact of an innovation that effectively sweeps aside much or even all of what previously represented the norm. In other words, it signifies a revolution of some kind. See section 5.2 for a fuller discussion.
- 57 Formerly known as the Consultative Group for International Agricultural Research, CGIAR is a global partnership that unites international organisations engaged in research about food security.
- 58 See, for example, CGIAR: “Only 7% of agricultural innovation investment targets environmental outcomes, finds CoSAI study”, 20 August 2021.
- 59 Ibid.
- 60 See, for example, *Guardian*: “COVID-19 shows factory food production is dangerous for animals and humans alike”, 8 September 2020; and Kirchhelle, C: *Pharming Animals: A Global History of Antibiotics in Food Production (1935-2017)*, 2018.
- 61 Some 65% of businesses analysed for the 2020 edition of the Coller FAIRR Protein Producer Index did not disclose any information about their use of antibiotics. There has been progress since, although the 2022 edition reported several instances of companies embracing and then ceasing disclosure.
- 62 See, for example, United Nations Environment Programme: *Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission*, 2020. The report identified increasing demand for animal protein and “unsustainable agricultural intensification” as two of the key anthropogenic drivers of zoonotic disease emergence.
- 63 As discussed in more detail in section 7.1, FAIRR’s first major engagement with businesses in the food industry successfully targeted leading restaurant chains over their antibiotics policies.
- 64 Two Accenture researchers, Larry Downes and Paul Nunes, devised the shark fin to reflect an age of near-perfect information, knowledgeable consumers and almost relentless creative destruction. The model supposes that new ideas take off either suddenly or not at all and that adoption therefore either occurs all at once – followed by an equally precipitous decline in interest – or never happens. See, for example, *Harvard Business Review*: “Finding your company’s second act”, January/February 2018.
- 65 Professor Binks participated in this interview in 2021. He passed away in early 2022. The Professor Martin Binks Memorial Prize, an annual award for undergraduate students at Nottingham University Business School, has since been established. See, for example, GoFundMe: “Help fund the Martin Binks student prize”, 19 January 2022.
- 66 See Schumpeter, J: *Capitalism, Socialism and Democracy*, 1942.
- 67 See Bloomberg: “An investor presses his case against industrial-scale farming”, 10 December 2015, as featured in full in section 7.2.
- 68 See, for example, *New Scientist*: “Cane toad has surprise effect on Australian ecosystem”, 19 March 2015.

- 69 United Nations Secretary-General António Guterres used this term in launching the Intergovernmental Panel on Climate Change's latest report. See, for example, BBC News: "Climate change: IPCC report is 'code red for humanity'", 9 August 2021; and Intergovernmental Panel on Climate Change: *Climate Change 2021: The Physical Science Basis*, 2021.
- 70 Feynman, who helped develop the US's atomic weapons after joining the Manhattan Project at Los Alamos, reiterated his belief in nature's supremacy after he was asked to serve on a presidential commission tasked with investigating the *Challenger* tragedy (see section 5.1). Having laid bare the known vulnerability of the O-rings on the shuttle's solid rocket boosters when exposed to cold temperatures, he famously summed up the cause of the disaster by declaring: "Nature cannot be fooled." See Rogers Commission: *Report to the President by the Presidential Commission on the Space-Shuttle Challenger Accident* (Appendix F), 1986.
- 71 The global vegan market alone is expected to be worth more than \$60 billion by 2028. See, for example, Fortune Business Insights: *Vegan Food Market Size, Share and COVID-19 Impact Analysis, Product Type, Distribution Channel and Regional Forecast, 2021-2028*, 2022.
- 72 See, for example, CNN: "The best cities for vegans around the world", 11 April 2017; and *Treehugger*: "10 great cities for vegan and vegetarian foodies", 4 May 2022.
- 73 See, for example, Poore, J, and Nemecek, T: *Reducing Food's Environmental Impacts Through Producers and Consumers*, 2018.
- 74 See, for example, Monday Campaigns: "Go Meatless Monday – it's good for you and good for the planet", 2022; and *Veganuary*: "Join the plant-based revolution", 2022.
- 75 See, for example, Adam Smith Institute: *Don't Have a Cow, Man: The Prospects for Lab-Grown Meat*, 2018.
- 76 See, for example, Sustainalytics: "2020: the year of the flexitarian", 21 May 2020.
- 77 See, for example, Brand Essence Research: *Plant-Based Food Market Size, Share and Trends Analysis Report*, 2023; and Meticulous Research: *Plant-Based Food Market: Global Opportunity Analysis and Industry Forecast (2022-2029)*, 2022.
- 78 Visit FAIRR's Sustainable Proteins Hub at www.fairr.org for more details. See also, for example, *Food Manufacture*: "Record year for investment into meat alternatives", 3 March 2022; and Good Food Institute: "A deeper dive into alternative protein investments in 2022: the case for optimism", 16 February 2023.
- 79 See, for example, *Parliament Magazine*: "Strengthening responsible use of antibiotics in animal health", 1 December 2021.
- 80 See, for example, BBC News: "Caged animal farming: EU aims to end practice by 2027", 30 June 2021.
- 81 See, for example, European Commission: "European Green Deal: Commission presents actions to boost organic production", 25 March 2021.
- 82 See, for example, *New York Times*: "Sri Lanka's plunge into organic farming brings disaster", 7 December 2021.
- 83 See FAIRR: *Collier FAIRR Protein Producer Index*, 2022, for a detailed analysis.
- 84 See Good Food Institute: "Overall plant-based food market", 2021.
- 85 See, for example, Good Food Institute: *2022 State of the Industry Report: Plant-Based Meat, Seafood, Eggs and Dairy*, 2023.
- 86 See Quantis and Impossible Foods: *Comparative Environmental LCA of the Impossible Burger with Conventional Ground Beef Burger*, 2019.
- 87 See Poore, J, and Nemecek, T: *Reducing Food's Environmental Impacts Through Producers and Consumers*, 2018; and *Independent*: "Veganism is 'single biggest way' to reduce our environmental impact, study finds", 24 September 2020.
- 88 It is important to note that those who exercise their personal choice to eat meat can also make a difference, as observed earlier in this section, by moving from consuming the products of industrialised agriculture to consuming the products of more responsible, sustainable, animal-welfare-centred methods of farming.
- 89 Visit FAIRR's Sustainable Proteins Hub at www.fairr.org for more details.
- 90 See, for example, *New Atlas*: "Animal-free dairy milk set to finally hit US retail shelves", 28 February 2022.
- 91 See, for example, *Food Navigator*: "Feeding plant-based innovation: 'Fermentation is the future of the alternative protein industry'", 30 April 2020.
- 92 Ibid.
- 93 Private investments in fermentation now exceed those in cultivated meat. Plant-based technologies continue to lead the way. Visit FAIRR's Sustainable Proteins Hub at www.fairr.org for more details.
- 94 See, for example, SeafoodSource: "New cross-value-chain project accelerating innovation in salmon aquaculture", 8 October 2021.
- 95 See, for example, NFU: *Achieving Net Zero: Farming's 2040 Goal*, 2019.
- 96 See, for example, Rockefeller Foundation: *Food & Prosperity: Balancing Technology and Community in Agriculture*, 2013, which notes how the scientists who laid the foundations for the Green Revolution were determined to find an answer to the "tragedy of hunger". One remarked: "I certainly would have been almost wicked not to have done what a person could do to help out".
- 97 See, for example, Downes, L: *The Laws of Disruption*, 2009.
- 98 See, for example, *Harvard Business Review*: "Reckoning with the pension fund revolution", March/April 1991.
- 99 See, for example, Organisation for Economic Cooperation and Development: "Pension funds in figures", June 2021.
- 100 See, for example, FAIRR: *The Restaurant Sector and Antibiotic Risk: Progress Report*, 2017.
- 101 See, for example, *USA Today*: "California meat-packer to pay \$317m over abuse, recall", 16 November 2012.
- 102 See, for example, *Food Dive*: "How two years of changes in dairy led to two major bankruptcies", 4 March 2020.
- 103 See, for example, *National Geographic*: "Where will we find enough food for nine billion people?", May 2014.
- 104 See, for example, *Our World in Data*: "Half of the world's habitable land is used for agriculture", November 2019.
- 105 See, for example, the World Economic Forum's nexus of interconnected causality, as featured in section 4.2.
- 106 Evidence of this transition is already mounting. One example is the recent shift towards pea protein: farmers in many regions of the world are increasingly growing peas rather than more traditional crops, with the global market predicted to be worth almost \$3 billion by 2027. See, for example, *Time*: "The rise of the pea: how an unassuming legume emerged as a frontrunner in the race to replace meat and dairy", 15 August 2019; and Cision: "Pea protein market size is expected to reach \$2.9 billion by 2027", 1 August 2022.
- 107 See, for example, Reuters: "Opinion: why our broken food system is overshooting the Earth's planetary boundaries", 29 July 2021.
- 108 See World Wide Fund for Nature: *Appetite for Destruction*, 2017.
- 109 See Intergovernmental Panel on Climate Change: *Special Report on Climate Change and Land*, 2019.
- 110 See Cottrell, R, Nash, K, Halpern, B, Remenyi, T, Corney, S, Fleming, A, Fulton, E, Hornborg, S, John, A, Watson, R, and Blanchard, J: *Food Production Shocks Across Land and Sea*, 2019.
- 111 See Food and Land Use Coalition: *Growing Better: Ten Critical Transitions to Transform Food and Land Use*, 2019. The report suggested: "The hidden costs of global food and land use systems sum to \$12 trillion, compared to a market value of the global food system of \$10 trillion."



Jeremy Coller

Jeremy Coller is Chief Investment Officer and Managing Partner of Coller Capital, a leading secondary private equity business, which he founded in 1990.

In 2015 Jeremy founded the FAIRR (Farm Animal Investment Risk and Return) initiative, which is the fastest-growing investor network focused on ESG risks and opportunities in the global food sector. Through the Coller Foundation, Jeremy has launched the Coller Animal Law Forum (CALF) and a number of other initiatives dedicated to accelerating the transition away from intensive agriculture. Jeremy is also founder of CPT Capital, which invests in solutions and alternatives to intensive agriculture, and is President of the Alternative Proteins Association.

He holds an MA in Philosophy from Sussex University and a BSc (Hons) in Management Sciences from the University of Manchester, UMIST.