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SPECIAL REPORT BY **DAN SALADINO**
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Biodiversity in farming and nature

Our food system is both the cause and the victim of unprecedented destruction. In our efforts to feed a growing population we have destroyed vast amounts of the Earth's biodiversity, including many of the plants and animals we have relied upon for food. Now, as we stand on the brink of environmental and social crisis, we urgently need to preserve what diversity remains, for both the future of our species and that of the planet.

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PHOTO: ARTUR MELEZ TIXILISKI

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Biodiversity in the spotlight – at last

The word 'biodiversity' has only recently gained currency because humans are in the process of destroying what it refers to. But this moment of crisis also represents an opportunity to galvanize actions and ideas that will heal the planet and protect the generations to come.

Diversity is a key to resilience – short and long term.

PHOTO SOURCE: GETTY IMAGES

The rapid loss of the world's biological diversity, often referred to as 'biodiversity', is increasingly recognised as one of the most pressing issues of our time. Sitting alongside and interlinked with climate change, this crisis needs addressing. There is no time to lose.

Over millions of years, the Earth built up a truly astonishing number of living species. For most of human history, we have been able to make use of this biodiversity and even add to it. Since the industrial age however, we have waged a war against diversity, endangering many of the Earth's crops, fruits, vegetables, animals, fish and wild plants and, in some cases, even driving them to extinction. In the last century this process has accelerated, threatening entire ecosystems and our planet's biosphere. And the leading culprit for this acceleration, according to many experts, is the modern food system. From the way we have transformed landscapes, to how we have plundered natural resources, to what we have chosen to eat, the process by which we produce, distribute, and consume food has become a destructive force.

Through innovation and scientific know-how, we have succeeded in feeding more people more cheaply, but in a way that relies on just a few high-yielding

crop varieties and animal breeds while requiring huge amounts of energy. In our desire to create more food, we have covered the planet with a blanket of homogeneity.

As we head into a more turbulent and uncertain future, scientists, governments and the food industry are waking up to the realisation that we all depend on biodiversity – it provides the foundations for food security, for human health and for the health of our planet. With creativity and imagination, we can develop ideas that will transform our food system, repair at least some of the damage we have inflicted, and safeguard the diversity that remains, but we need to act now.

A date that should go down in history as one of the big wake-up calls on the biodiversity crisis is September 23, 2019. On this day, the United Nations held a Climate Action Summit at its headquarters in New York. Government leaders, corporate CEOs and scientists gathered together to try to find solutions to an emergency. *"In the face of worsening climate crisis, practical action needs to shift into a higher gear,"* the UN's Secretary-General António Guterres said at the event's opening. *"This is not a climate talk summit. We have had enough talk; this is not a climate negotiation summit. You don't negotiate with nature. This is a climate action summit."* The preceding four years had been the four hottest on record, he explained, *"and we are starting to see the life-threatening impact of climate change on health… and risks to food security."*

Later that day, summit attendees heard another speech – less reported in the press but equally powerful – that addressed not climate but biodiversity. The speech was remarkable not so much because of its message (warnings about the loss of biodiversity had been issued for many years before), but because of its messenger: it came from some of the major corporations that make up the global food industry.

"The food system that we have built over the last century has become a dead end."

EMMANUEL FABER,
CHAIRMAN & CEO, DANONE

"The food system that we have built over the last century has become a dead end," said Emmanuel Faber of the French dairy business Danone, on behalf of twenty businesses that included Unilever, Nestle, Mars and Kellogg (with combined sales, in more than 100 countries, exceeding $500 billion a year). *"We thought we could select and engineer the life that we needed and kill the rest in the fields. The resulting mono-cropping means that two-thirds of the world's food supply depends on only nine plants and much of the world's dairy cattle is based around one single breed of cow, the Holstein. From a resilience standpoint, we are in a very risky situation if anything happens to any of these species… In a nutshell, we have broken the cycle of life and [removed] the biodiversity in our fields. We have created a food system that has focused on economies of scale and simple solutions, but it's over-simplistic now. We have a complete loss of diversity… We've been killing life and now we need to restore it, day by day, one by one."*

For some of the major players in the world's biggest food supply chains to spell out this dire warning marked a turning point in the global conversation about biodiversity. They were acknowledging that the food system was broken, that biodiversity was being lost, and that urgent action, innovation and problem solving were necessary to save it. For their part, Danone and the other food businesses represented made a pledge on that day "to create a demand for a variety of crops, of species, of traditional seeds that are forgotten today and that are dying."

Those corporations recognized a simple truth: the biodiversity crisis is so urgent that we all need to play a part in helping to fix it. The world will need ambitious, transformative ideas.

Defining diversity – the infrastructure of life

Biodiversity is the most complex feature of our planet and it is the most vital. Without biodiversity, there is no future for humanity.

Almost 90% of the world's oceans have been "significantly altered" by human action, while only 13% survive as marine wilderness.[2]

PHOTO SOURCE: IPBES

Biodiversity refers to the variety of life on Earth, in all its forms, interactions, and scopes – from genes to species to entire populations – that has evolved over billions of years. The term was coined in the mid-1980s by a group of academics who had gathered in Washington DC to discuss their concerns over the decline in the diversity of life.[1] *"Much of diversity is being irreversibly lost through extinction caused by the destruction of natural habitats,"* said the American conservationist EO Wilson, one of the event's organisers. *"We are locked into a race. We must hurry to acquire the knowledge on which a wise policy of conservation and development can be based for centuries to come."* Nearly four decades on, the world is finally catching up with this line of thinking.

At its simplest, biodiversity refers to the variety of all life on Earth, the truly staggering array of life forms that populate our planet's biosphere, from bacteria to bison, plants to people. However, biodiversity is far more than just the abundance of life on Earth and an exercise in counting numbers. The complexity and interconnectedness of the planet's biodiversity is what maintains the resilience and adaptability of the environment as a whole. As EO Wilson poetically described, *"It is the assembly of life that took a billion years to evolve.*

It has eaten the storms – folded them into its genes – and created the world that created us. It holds the world steady."

This assembly of life comprises three different but connected components. One is **species diversity** (the concept of biodiversity most of us are familiar with – the incredible array of animals, plants and micro-organisms in the world). Of the 9 million or more estimated species on Earth, we've identified just 1.2 million.

"We now have overwhelming evidence that more and more animals, plants and other life forms are facing an uncertain future and that the primary driver for this is our global food system."

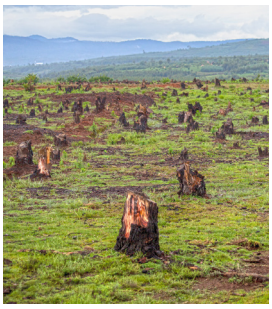
Then there is **genetic diversity,** which is the variety of genes contained in those plants, animals, fungi and microorganisms. This variety can be examined between species but also within species, for instance within our own (we all have different alleles or gene variants that result in our individual eye and hair colour) or as seen in the potential diversity of the world's major food crops. In gene banks around the world, there are 469,000 accessions (unique samples) of wheat, 251,000 of rice, 3,200 of bananas, nearly 25,000 of potato and 23,700 of apple.[3] The viability of our food system is dependent on this genetic diversity; these varieties or cultivars are all adapted to their local conditions and possess valuable traits suited to different conditions, from drought to flooding, poor soils to diseases. They provide the toolkit for the future of all of our food. When we lose a variety of plant or breed of animal, our food system loses some of its ability to adapt to changing conditions. We lose options and we lose resilience.

And then there is **ecosystem diversity,** which is the variety of habitats on the planet where species interact with each other and with the sunlight, air, soil and water to form unique ecosystems, from the Arctic tundra to the African Savannah, from rivers to the deep sea. An ecosystem can be as large as the Great Barrier Reef or as small as a rockpool containing sponges, algae, worms and crabs.

Together, this biological diversity provides the infrastructure that supports life on Earth. What all three components of biodiversity also have in common is that they are all in rapid decline. We now have overwhelming evidence that more and more animals, plants and other life forms are facing an uncertain future and that the primary driver for this is our global food system.

Biodiversity under threat – living through the Earth's sixth mass extinction

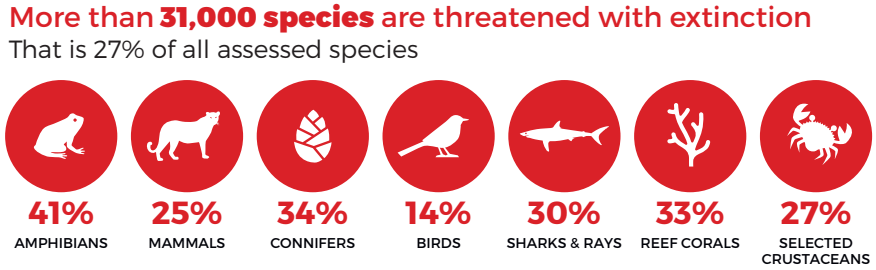
One million animal and plant species are now threatened with extinction, with human need for food and energy being the main drivers.



In the Tropics and sub-Tropics, the expansion of large-scale agriculture accounted for 40% of forest loss between 2010 and 2015 alone.

PHOTO SOURCE: IPBES

The scale of the world's biodiversity loss was laid bare in a United Nations report published in 2019, a global assessment of nature compiled over three years by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In the report, the authors plotted two diverging trend lines: one, upward-sloping, for humans, and the other downward-sloping, for everything else on the planet. During the past fifty years, the planet's human population has doubled. In that same period, the size of the global economy has quadrupled and global trade has grown tenfold. Although hundreds of millions of people around the world still live in poverty and hunger, there are many more people living in prosperity today than at any time in history, and we grow and produce more food than ever before. The downward trend – the price being paid – was the Earth's intricate and interconnected web of life: biodiversity. Through sophisticated modelling, the 145 scientists behind the Global Assessment concluded that one million animal and plant species are now threatened with extinction, with the human need for food and energy as the main culprits.



One in four species is at risk of extinction.

SOURCE: IUCN RED LIST OF THREATENED SPECIES.

The International Union for Conservation of Nature (IUCN), the global authority on the status of the natural world, has also documented rates of extinction. Its Red List of endangered species is another reliable indicator of the health of the world's biodiversity. Currently, more than 30,000 species are listed as threatened with extinction, which is 27 per cent of all assessed species (birds, mammals, plants and insects). Of course, extinctions are nothing new. In the Earth's history, five mass extinction events have occurred, including the one that ended the Mesozoic Era, also known as the age of dinosaurs, just over 60 million years ago. As human populations continue to grow, however, extinction rates have been accelerating, which is why many scientists believe we are living through a sixth mass extinction. This time, however, humans rather than natural events are to blame.

"More of the world wants to eat more of the same types of food, prime examples being the beef desired by consumers, and the palm oil now considered an 'essential' component of processed, industrialised food."

Driving this decline in biodiversity is the increased demand for food from a growing global population and, specifically, its growing appetite for a small selection of food 'staples.' More of the world wants to eat more of the same types of food, prime examples being the beef desired by consumers, and the palm oil now considered an 'essential' component of processed, industrialised food. Between 1980 and 2000, 100 million hectares of tropical forest were lost, mainly to cattle ranching in South America and palm oil plantations in South East Asia in an effort to satisfy the world's insatiable appetite for these foods.

"Land use now appears as the major driver of the biodiversity collapse, with 70 per cent of agriculture related to meat production," says Yann Laurans, Biodiversity and Ecosystems Director at IDDRI, the French policy research institute. *"It is time to reconsider the share of industrial meat and dairy in our diet."*[4]

It's a similar story at sea. Almost 90 per cent of the world's oceans have been "significantly altered" by human action, while just 13 per cent survive as marine wilderness.[5] Overfishing has created a situation so fragile and placed fish species under such extreme pressure that one in ten global fisheries (the vast commercial fishing grounds of the oceans) have completely collapsed. The pressure is ongoing: a third of all marine fish stocks are currently caught at unsustainable levels, while 60 per cent are already being fished at the limits of sustainability.

Agricultural activities have had the greatest impact on the very things we all depend on: food, clean water and a stable climate.

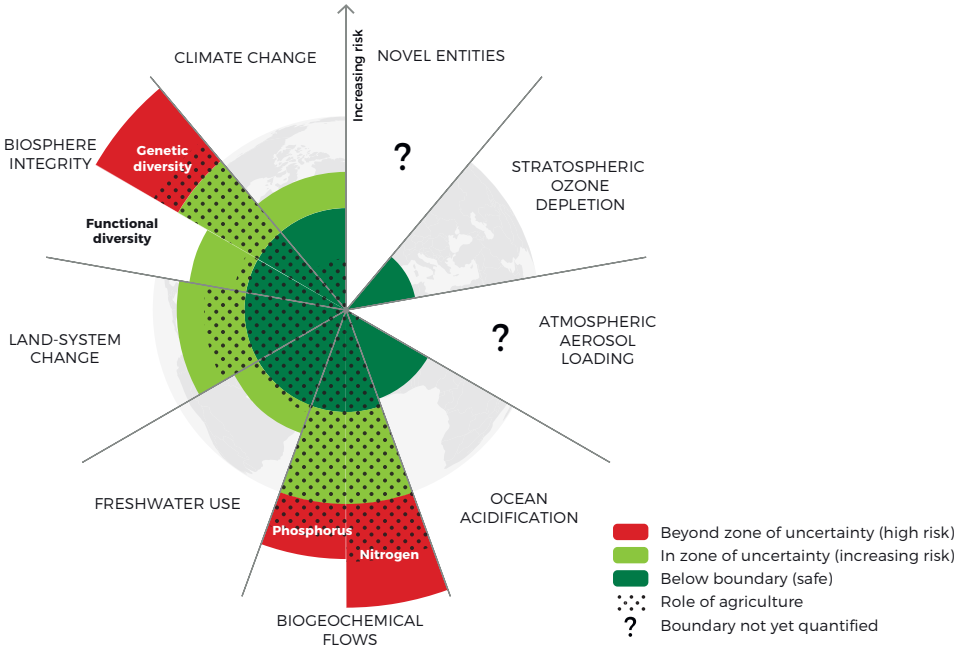
PHOTO SOURCE: IPBES

In 2019, the United Nations Food and Agriculture Organisation (FAO) published another landmark report, The State of the World's Biodiversity for Food and Agriculture. It reveals that, of the 6,000 plant species humans have cultivated for food, a mere nine now account for two-thirds of all crop production, and that, of the nearly 8000 local breeds of farm animals that exist, only a

handful are raised for global livestock production. The report estimates that a quarter of all local breeds are now at risk of extinction (though many experts believe the reality is far worse) and emphasizes that the loss of this genetic resource makes our food supply, and our future, far more vulnerable. Between 2010 and 2015 alone, the FAO found, the expansion of large-scale agriculture in the Tropics and sub-Tropics accounted for 40 per cent of forest loss – a vivid illustration of just how quickly this grim transformation is occurring.

Agricultural activities are also some of the largest contributors to human emissions of greenhouse gases. In fact, they account for roughly 25 per cent of total emissions thanks to the use of fertilisers and the conversion of areas such as tropical forests to grow crops or raise livestock such as cattle. Agricultural threats to ecosystems will only increase as the world's population continues to grow, according to the IPBES analysis.[6] What's more, agricultural activities have had the greatest impact on the very things we all depend on: food, clean water and a stable climate.

Another way of understanding the threats we face from biodiversity loss is through the concept of planetary boundaries and a safe operating space for humanity. In 2009, Johan Rockström, a professor of environmental science internationally recognised for his work on global sustainability issues, proposed the concept, and hypothesized that crossing these boundaries (for example, land-system change, freshwater use and climate change) could generate unacceptable environmental upheavals, potentially endangering human existence itself.[7] Recent analysis reinforces this notion of boundaries, and shows how biodiversity loss is taking us – and the planet – into high-risk scenarios.



The status of the nine planetary boundaries. Overlaid with estimate of agriculture's role in that status.
SOURCE: CAMPBELL ET AL. 2017 BASED ON ROCKSTRÖM ET AL. 2009

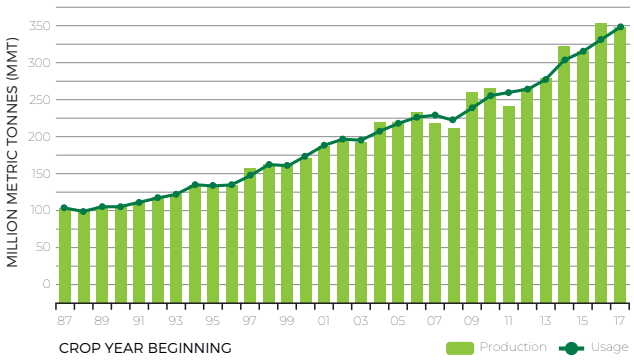
A stark example of how agriculture is impacting land use and biodiversity can be found in the Cerrado, Brazil's equivalent to the African savanna. Less well known than its neighbour the Amazon, the Cerrado ranks as one of the world's richest centres of biodiversity. A patchwork of grassland, forests, wetlands and woodlands the size of Germany, France, Italy, Spain and the UK put together, it is home to 5 per cent of all of the Earth's animals and plants.[9] It contains more than 11,000 species of trees and plants, nearly half of which are found nowhere else. As well as incredible plant diversity, the Cerrado is also home to 200 species of mammals, including jaguar, maned wolves, giant anteaters and nearly 900 species of birds. A lot of the ecosystem is hidden from view, however, as the root system of the Cerrado goes so deep it's been likened to an upside-down forest; seventy-five per cent of the area's plant life is underground. This is why the Cerrado is one of the world's major carbon sinks and why its preservation is thought to be vital in the fight against climate change.

"Land use now appears as the major driver of the biodiversity collapse, with 70% of agriculture related to meat production".

YANN LAURANS, BIODIVERSITY AND ECOSYSTEMS DIRECTOR AT IDDRI, THE FRENCH POLICY RESEARCH INSTITUTE.

Since the 1950s, agriculture has wiped out about half of all of the Cerrado's native vegetation and, by 2030, Brazil's savanna is projected to lose tens of millions more acres to farming. One of the main drivers of this loss of biodiversity is a single crop: soybeans. This small legume, first domesticated in China thousands of years ago, has gone from relative obscurity in the 1970s to become Brazil's main commodity, with exports of it valued at more than $33 billion. Most of Brazil's soybean harvest is destined for livestock feed as protein for pigs, chickens, and cattle.[10]

World Soybean – Production vs Usage[11]



SOURCE: SOYBEAN MEAL INFO CENTRE

In Brazil, soybeans grown for livestock feed and export drive out other crops.

In October 2019, an investigation by a Brazilian NGO found that more than 6.5 million acres of Brazil's soybean plantations were cultivated on unregistered lands in the Cerrado and Amazon, making them, effectively, illegal farms. The bulk of these soybeans was being exported to China and the European Union – feeding a large appetite for industrially produced meat.[12] The world's demand for meat has grown in the last half century – and so far, we have been

able to appease it. In the USA, meat consumption is now 100kg per person and 71kg per person in the EU. In 1961, the average Chinese person ate 4kg of meat a year but by 2013 this had increased to 62kg and it's expected to rise further. Half of the Cerrado has already been lost, but thanks to that growing demand, we're in serious danger of losing much of what remains in the next decade.

> Western man has made more difference to his diet in the last 150 years or six generations than during his previous one million years on earth or 40,000 generations.
>
> Denis Burkitt, British surgeon and public health pioneer

The rise of the Global Standard Diet

"Western man has made more difference to his diet in the last 150 years or six generations than during his previous one million years on earth or 40,000 generations."

Denis Burkitt, British surgeon and public health pioneer

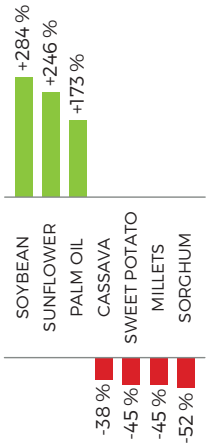
As the world succumbs to the global standard diet, chicken and rice have replaced traditional local foods.
PHOTO SOURCE: GETTY IMAGES

The world's food and farming systems evolved over millennia, and for the most part they were shaped by natural systems and within planetary boundaries. If you look at the origins of any farming system around the world, you will find similar patterns, such as the pairing of cereal crops with legumes. In Mexico's 'milpa' system – an ingenious farming system where different crops support each other, naturally enrich the soil and provide people with a perfectly balanced diet – corn was grown with lima and pinto beans; in China, millet (and later, rice) grew alongside soybeans; in India, cereals were planted with mung beans; and in Africa, cowpeas with sorghum. In all these cases, the combination of cereal and legume crops makes for a healthy balance of nutrients, and has fueled gastronomy:[13] the world's most celebrated cuisines, from Chinese and Indian, to Provençal and Tuscan, and Turkish to North African, all feature combinations of cereals and pulses. In other words, diversity was an essential tool in traditional farming – with crops complementing each other – and diversity was also a means of ensuring good health and good flavor.

But as The Ark of Taste, an online catalogue of endangered foods compiled by the Slow Food movement, illustrates, many traditional food cultures are disappearing and with them, the farming systems, crops, breeds and skills that underpin them. To date, the Ark of Taste has recorded more than 5000 endangered foods in more than 100 countries.

Over the past fifty years, a 'global standard diet' has been replacing the world's diverse food cultures, with the majority of the world now eating a diet composed of a small number of commodity crops, mostly wheat, rice, potatoes and sugar. This global standard diet also includes crops that were considered marginal fifty years ago, but which, in the span of a few decades, have become important to the diets of billions of people, like soybeans and palm oil.

A decade ago, a team of researchers led by American plant diversity expert Colin Khoury started to quantify exactly how the world's diet had changed over fifty years. They examined food supplies covering 1960 to 2010, using data sourced from the United Nations Food and Agriculture Organisation. For every country about which they could gather evidence (which covered 98 per cent of the world's population), they measured which crops were eaten and how many per capita calories and other nutrients each of the foods delivered. They identified massive changes in eating patterns since the 1960s that have resulted in a kind of dietary homogeneity. Wherever in the world you happen to live, in other words, you now have access to much the same menu of core ingredients as someone who lives 1,000 miles away in any direction. Khoury and his team referred to this phenomenon as the 'global standard diet'.



Winner and losers: in the past 50 years, traditional, nutrient-dense foods like millet and sweet potatoes, have been replaced by the homogenous staples of the Global Standard Diet.

SOURCE: PNAS JOURNAL

Beginning in the 1960s, we started to eat more refined grains, more fat, more sugar and fewer pulses and beans. In short, the global diet has become sweeter, oilier and meatier and we are now highly dependent for our sustenance on foods that have been grown or produced far away from the place where we live. The average eater gets the bulk of his or her daily calories from just six sources: animal foods, wheat, rice, sugar, maize and soybeans. As a result, there has been a startling shift away from multiple traditional diets towards a single, modern one.

Crops which showed a decline during the five decades studied were nutrient dense foods such as millets, rye, yams, sweet potatoes and cassava. When the researchers calculated the shift in global diets, they found that the variation between food supplies in different countries had decreased, on average, by 69 per cent. This dietary convergence, Khoury's study also found, came with a high cost to human health.

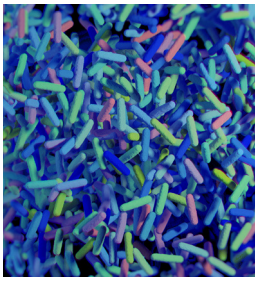
The homogenisation of the global diet is helping to accelerate the rise in non-communicable diseases, such as diabetes and heart disease, problems that are increasing worldwide.

As well as the trend towards homogenisation, the researchers also found an increase in the quantities of food eaten. In 1961, people on average consumed 2237 calories per day; that amount now is 2756 – an increase of nearly 500 calories. What's more, each year an estimated one third of all food produced – equal to 1.3 billion tonnes worth around $1 trillion – ends up rotting in the bins of both consumers and retailers or spoiling due to poor transportation and harvesting practices.[14] We are destroying biodiversity to produce food that no one gets to eat.

By eating the same diet as everyone else, we are also, worryingly, putting all our eggs metaphorically in one basket. The winnowing of diversity makes agriculture far more vulnerable to the major threats posed by climate change: drought, pests and disease. If we rely on only a small variety of crops (which we do) and those crops fail, huge swathes of the world's population will be affected.

Our own biodiversity loss: The human gut microbiome

Declining biodiversity in the food system is reducing the diversity of the bacteria living in our guts, with implications for our health.



Microbes, living in amazing diversity inside our gut, can weigh up to 2kg.

PHOTO SOURCE: GETTY IMAGES

The decrease in crop diversity and rise of the global standard diet brings a wide range of health consequences for our species, including the effect on the human gut microbiome. The microbiome is something we all have but are only just beginning to understand; it's the trillions of bacteria and other microbes that live inside our gut. This population, which can weigh up to 2kg, helps digestion and makes a vital contribution to health. And just as we are only starting to realise the value of the biodiversity around us, so are we also beginning to slowly unravel the importance of the amazing microbial diversity inside us. Research has linked gut bacteria to how efficiently our body breaks down food, the health of our immune system and even to brain function.

From the day we're born, microbes start to populate our gut, but these are not permanent residents; the inhabitants of our microbial habitat come and go over time. The more diverse our diets, the more diverse our microbiomes, and research suggests that having a wide array of microbes in our gut makes our microbiome more capable and resilient. An important determinant of this diversity within the gut microbiome is diet. Which means that declining biodiversity in the food system also reduces the diversity of the bacteria living in our guts, with health implications for all of us.

Seeds, breeds and genetics: the science of monocultures

In little more than five decades, the rich, millenia-old crop diversity developed by farmers all around the world was rapidly replaced by a smaller selection of high-yielding, modern varieties.

Monocropping has transformed the world's landscape and reduced soil and ecosystem resilience.

PHOTO SOURCE: GETTY IMAGES

Modern farming has allowed us to select against diversity in a race to produce ever greater quantities of food. In the 20th century, we cracked the codes that made that process increasingly possible.

The word 'genetics' was coined in 1905, a time when botanists such as Roland Biffin, the first Professor of Agricultural Botany at Cambridge University, had started to develop the science of modern plant breeding, creating new types of higher yielding and more disease-resistant varieties of wheat. These botanists embraced the science of heredity – developed in the 1860s by Greger Mendel but initially ignored – and used it to start to change the global food system.

While Biffin was experimenting with wheat, an American plant breeder named George Harrison Shull carried out trials with corn that led to the development of so-called 'F1 hybrids'. Shull discovered that, by selecting varieties, inbreeding each one many times and then crossing the offspring together, it was possible to create an extraordinarily vigorous plant with abundant kernels. With the help of newly developed nitrogen fertiliser, these plants could also be planted close to each other, at high density, in field after field. This was the starting point for today's monocultures.

Another critical breakthrough took place in a lab in a district of Berlin in 1909, when the chemist Fritz Haber changed the future of humankind and our planet by "fixing" the chemical element nitrogen into liquid ammonia, and thereby created the basis for synthetic fertiliser. Using extreme temperatures and extraordinarily high pressures, Haber, with the help of his assistant Carl Bosch, created a means for synthesising nitrogen on an industrial scale, and in the process, addressed the problem of feeding the world's growing population. In fact, Haber and Bosch made it possible, as one observer noted, to "win bread from the air."[15]

Some have calculated that this process is responsible for the crops that feed nearly 45 per cent of the world's population, the equivalent of enough food for 3.25 billion people. As the science writer Charles C. Mann puts it, "more than 3 billion men, women and children – an incomprehensibly vast cloud of dreams, fears and explorations – owe their existence to two early-twentieth century German chemists."[16]

As the new, industrially-produced fertilisers became more widely available in the 1930s, a different kind of problem became apparent: crops grew so tall so quickly, and their grains so heavy, that they had a tendency to fall over in the wind and rot (a problem called lodging). This brake on productivity wasn't fully resolved until the intensive post-war plant breeding programme that became known as "the Green Revolution", and was sparked by Norman Borlaug's breeding of shorter, disease-resistant dwarf wheats.

"During the peak of the Green Revolution, between 1960 and 2000, the global use of synthetic fertiliser increased by 800%."

Concerns over global hunger sparked this explosion in plant science and agricultural innovation, and in that sense, it was a success: food crop production has increased by 300 per cent since 1970, providing the bulk of the calories for the global standard diet[17]. But this boom was entirely dependent on chemical inputs (nitrogen fertiliser and pesticides) and extensive irrigation. During the peak of the Green Revolution, between 1960 and 2000, the global use of synthetic fertiliser increased by 800 per cent.

The long-term impacts of this agricultural intensification on climate, pollution, oceans, and pollinators are well known. Less well-covered, however, is its erosive effect on gene diversity (one of the three pillars of biodiversity). In a relatively short span of time – a little more than five decades – the rich crop diversity developed by farmers all around the world over millennia was rapidly replaced by a smaller selection of high-yielding, modern varieties. Locally adapted varieties (so-called "landraces"), each one a genetically distinct cultivar, were displaced by higher yielding, genetically identical ones.

Take the example of Turkey, which is part of the "Fertile Crescent" where wheat was first domesticated twelve thousand years ago. In the 1920s, the unique landrace varieties of wheat grown by Turkish farmers numbered around 18,000. Following the Green Revolution and the arrival of Borlaug's new, high-yielding dwarf varieties in the 1960s, 95 per cent of that genetic diversity was lost.

From 2,000 types of rice to just a few. In Bangladesh, two-thirds of the rice grown today belongs to a single variety.

PHOTO SOURCE: GETTY IMAGES

The Green Revolution modus operandi was the same with rice as it was with wheat, the idea being to create a central breeding programme which could deliver a "one-size fits all" quick-fix solution. The International Rice Research Institute (the IRRI), the headquarters for this central strategy, was founded in 1960.

Within five years, after thousands of cross-breeding experiments, plant breeders created a variety of rice they called IR8. This shorter plant could produce larger grains without becoming so heavy that it would fall over (the same principle Borlaug had developed). In the late 1950s, Sri Lankan farmers were growing at least 2,000 different types of rice, but by the 1990s the nation's rice crop was dominated by just five. In Bangladesh, similar losses occurred, and today, almost two-thirds of the rice grown is based on a single variety. In Indonesia, this monocultural approach accounts for closer to three-quarters of the crop.

The Genetics of Disaster

We can survive if a forest or shade tree is destroyed, but who would survive if wheat, rice, or maize were to be destroyed? We are taking risks we need not and should not take.

In July 1972, as the Green Revolution wheat and rice varieties were spread around the world and planted across millions of hectares of land, the influential plant scientist Jack Harlan published an article called "The Genetics of Disaster." In it he wrote that while the world's population was increasing faster than at any time in human history, the diversity of edible plants was disappearing at an equally unprecedented rate. People were starting to wake up to the environmental consequences of the Green Revolution, but Harlan was worried that the disappearance of biodiversity was going unnoticed.

There was, he said, rightly, a *"hue and cry over pollution of the air, streams, lakes and seas…and dismay over the destruction of wildlife and natural beauty… [but] the erosion of some of the most vital resources for human survival goes on with no notice from the public and with very little attention from the scientific community."* Traditional crops and their valuable genetic traits, he said, were *"the result of millennia of natural and artificial selections and are the basic resources upon which future plant breeding must depend. These resources stand between us and catastrophic starvation on a scale we cannot imagine. In a very real sense, the future of the human race rides on these materials."*

Harlan gave some chilling examples: the potato blight that led to the Irish famine, the outbreaks of Dutch Elm disease that devasted entire forests. *"We can survive if a forest or shade tree is destroyed, but who would survive if wheat, rice, or maize were to be destroyed? We are taking risks we need not and should not take,"* he warned. For Harlan, the solutions developed in the Green Revolution were only good until they failed – and when they did, we'd be left facing disaster.

With traditional 'landrace' crops, no two are the same. But modern bread wheat, for instance, has been designed to be a monoculture. Each individual plant is a clone of the other, developed to produce the maximum amount of grain and to be ready to harvest at the same time. In other words, science has selected against diversity. **Science has enabled us to perform the same conjuring trick with the animals we eat.** Cows, pigs, sheep and chickens are now largely taken from a tiny gene pool of the highest yielding and fastest growing breeds.

The invention of artificial insemination in the 1950s was followed by a technique for creating frozen straws of sperm that make it possible for the genes of only a small number of animals to dominate the world's beef and dairy supply: one bull can father half a million offspring in fifty different countries. This is how the Holstein breed of cow (whose milk yield has been tripled by breeders and geneticists) is now responsible for producing about 95 per cent of all the world's milk. Of animal breeds that have survived into the 21st century, 60 per cent are at risk of extinction, including the Fogera cattle in Ethiopia that can survive drought and Pantaneiro cattle in Brazil, which are renowned for their resistance to many diseases.

"The invention of artificial insemination in the 1950s was followed by a tech-nique for creating frozen straws of sperm that make it possible for the genes of only a small number of animals to dominate the world's beef and dairy supply."

A dangerously narrow gene pool in the Holstein family.

PHOTO SOURCE: GETTY IMAGES

Most intensively reared pigs in the world come from one breed, the Large White. Most industrial chickens contain the genes of a chicken called the Vantress, the result of a competition launched in 1950s America to find the 'chicken of tomorrow,' defined as a meaty bird that could compete with beef. But with so much of the world's population increasingly dependent on chicken as a primary source of protein, their genetic uniformity leaves them – and us – vulnerable on a global scale; a disease that afflicts a flock in Mexico, for example, can spread easily through the Americas, Europe, and Asia, wiping out the same breed around the world.

The intensive model is now showing signs of weakness. Green Revolution grains have hit a production ceiling; since the 1980s, wheat yields have plateaued. And many of the varieties, grown in vast monocultures, are increasingly being impacted by disease.

Scientists are urgently looking for disease-resistant crops among old landrace varieties. This is especially important for wheat where a high diversity of old varieties have been displaced by a small number of high yielding strains.

PHOTO: MAREK STUDZINSKI

The trouble with selecting for one trait, such as the ability to produce higher yields, is that other traits like disease resistance, can be lost. In April 2016, thousands of farmers in Bangladesh were told to set fire to their fields of unharvested wheat and throw away seeds they had saved from the year before. Their fields were infected, their government told them, with a fungal disease that had already devastated crops in South America. This disease, wheat blast, is carried from plant to plant by the wind and had already cut harvests in parts of Brazil and Bolivia by two-thirds. It arrived in Bangladesh on a shipment of imported grain and has spread through South Asia ever since.[19]

The fungus infects spikes of wheat and turns the plant a pinkish colour, covering the grains in black spots. Soon after, the grains shrivel and deform, and the crop is destroyed. In parts of south western Bangladesh, the disease has reduced wheat production by half, despite all the crop burning and tonnes of fungicides being used. If the fungus spreads into India and Pakistan, it will be disastrous; since the Green Revolution, the region's dependence on wheat has doubled – as people become richer, they have tended to switch from rice to wheat.[20]

Scientists are urgently looking for disease-resistant wheats. One place they think they might find them is in old landrace varieties. After all, looking to 'old' varieties has worked before.

In the late 1940s, Jack Harlan came across a field of wheat in a remote part of Eastern Turkey that had been saved by a farmer. Although it was "a miserable looking wheat, tall and thin-stemmed", he picked a few samples and took it back with him to the USA. This is where it remained, ignored and stored in a seed bank for two decades. In the 1960s, when a disease broke out in the wheat fields of the American north-west, plant breeders took a closer look at Harlan's Turkish wheat and found it had resistance not only to the current outbreak but

also to fourteen other diseases that had affected the crop. Tonnes of food and millions of dollars were saved because of that "miserable looking wheat."

"Biodiversity is our safety net."

Our crops are going to face even bigger risks in the future. For every degree Celsius increase in global temperature, yields of wheat are forecast to fall by 6 per cent.[21] Further climate change is also likely to increase the frequency and severity of crop diseases. Biodiversity is our safety net.

The Cavendish crisis – the clone banana under attack

Genetically identical and infertile, the seedless, commercially grown banana is unable to defend itself against pathogens, adapt, and evolve.

The dangers of replacing diversity with monocultures is evident right now in a crisis facing the banana industry. News broke last year that a fungal disease that can attack and kill entire plantations had been detected in Latin America for the first time. This is a strain of the Fusarium fungus, which causes so-called Panama disease. The problem is serious for the vast majority of the world's commercially grown and traded bananas, which are all clones of a single variety called the Cavendish.

Not able to reproduce itself, the Cavendish clone banana is now under threat from a fungal disease.

PHOTO SOURCE: GETTY IMAGES

While the fungus is not harmful to humans, it has the potential to eventually wipe out Cavendish bananas, according to experts. Millions of people around the world rely on bananas and plantains as a staple food and as a cash crop, and while there are more than 1,000 varieties of bananas, in different colours, shapes and sizes, nearly half of global production is the Cavendish type.

The Cavendish is planted in such huge numbers because it is easier to transport than other varieties and also gives high yields per hectare. Because of the way it has been bred, the Cavendish has lost the ability to reproduce itself, which means every Cavendish banana is a clone of another. As it can't reproduce itself from seed, it can no longer adapt and evolve, which means that if a pathogen is able to attack one tree on a plantation, it can attack them all. Planting huge swathes of monocultures filled with clones has left the global banana crop very vulnerable. While banana farmers around the world are watching as their crops are devastated, scientists are working to find genes resistant to this disease. And one of the places they are looking is in wild bananas, hoping that if they can give the Cavendish some of its ancient DNA back, it may be better able to protect itself.

When vast monocultures replace diversity, the natural system of pollination is broken, and blossoms will yield no harvest.

Losing pollinators – and diversity-based cross-pollination

When vast monocultures replace diversity, the natural system of pollination is broken, and blossoms will yield no harvest.

Nature, the IPBES report observed, "is essential for human existence" and the clearest example of this is in the role of pollinators in food production. Ninety per cent of flowering plants and 75 per cent of all types of food crops rely on pollination by wildlife – including birds and bats but mostly insects. Coffee and cacao (used in chocolate production) are examples of cash crops that are pollinator-dependent. In many regions, important pollinators, such as native bees, are in decline, and one of the major factors has been our reliance on pesticides. These chemicals are supposed to prevent crop failures by killing pests; the danger is that they may end up causing them. But our disruption to the process of pollination isn't just a result of our use of pesticides.

China's giant pear orchards provide a good illustration of the risks we create when we don't preserve diversity – to say nothing of how nature is cleverer than science. The county of Hanyuan in south-western China produces more pears than anywhere else in the world.

When the pear trees are in blossom, workers painstakingly pollinate each blossom by hand. They are equipped with a pair of sticks, which have chicken feathers stuck to one end and a cigarette filter to the other, and they have a small jar containing tiny yellow grains of pollen hanging from their necks. By gently brushing the feathers and filters against millions and millions of flowers, these workers do the work once carried out by bees.

Doing bees' work; pollinating pear trees by hand in south-western China. PHOTO CREDIT: KEVIN FRAYER.

It takes about five hours to pollinate thirty trees, as each individual flower needs to be dusted with pollen several times. But this anecdote isn't a futuristic story about what we will do when the world's pollinators have gone extinct. The story is, in fact, more complex. It helps bring home to us the importance of biodiversity.

In the 1980s, when China launched a huge drive to become self-sufficient, it massively scaled up its fruit industry. Hanyuan was turned into a giant fruit orchard and China is now the world's number one producer of pears, producing 16 million tonnes of the fruit a year.

"90% of flowering plants and 75% of all types of food crops rely on pollination by wildlife – including birds and bats but mostly insects."

In the past, householders in Hanyuan kept mixed orchards of fruit, including apples, citrus, cherry, peaches, plums and apricots, as well as a range of pear varieties. They also had beehives. When pear production was ramped up, there was a switch from small to large scale production, with the government providing trees of a handful of modern varieties of high yielding pears to be planted. The varieties had been carefully chosen because they were known to bloom at the same time of the year, which meant the different types of pear could cross-pollinate with each other, so ensuring that the trees fruited.[22]

When, a few years later, the government called on farmers to increase their production of pears yet again, one variety was highlighted as selling better than others: Jinhuali. As a result, more trees of this variety were planted and most of the other varieties removed. The plan backfired when it was realised that Jinhuali wasn't being pollinated; it couldn't do this by itself, even with the help of bees. It needed another variety of pear to help and most of these were now gone. Without these other varieties, Jinhuali trees could produce lots of flowers, but no fruit.

Some fruit varieties are capable of self-pollinating without any input from bees, but most pears and apples can't be fertilised with their own pollen. This hadn't been an issue for farmers in Hanyuan before because they had traditionally grown such a wide range of plants that there were always plenty of varieties for pollination to take place. What's more, the villages were surrounded by wild pear trees so bees could pass around an enormously wide range of different pollen. But when vast monocultures of pear trees replaced all of this diversity, the natural system of pollination was broken and pollen had to be brought into the orchards from outside.

To achieve food resilience, we need to think big and small

Regenerating the world's biodiversity and fostering higher levels of diversity in our food system is essential for security and resilience – and ultimately for our survival.

To arrest the decline and biodiversity and achieve food resilience, maybe we need a more TUNA world. Many people who think about the future of the planet use a marine-inspired acronym, TUNA, that when applied to the environment, captures many of the challenges we are creating and will be facing.

T stands for ***Turbulent:*** we will be seeing less stability in long term conditions. U is for ***Uncertain*** – because the future is increasingly difficult to predict. N is for ***Novel,*** as many of the challenges we face will be new and we will have no tried and tested remedies on hand. And A is for ***Ambiguous,*** because there are no clear paths we can follow; whichever action we take, there will be winners and losers.

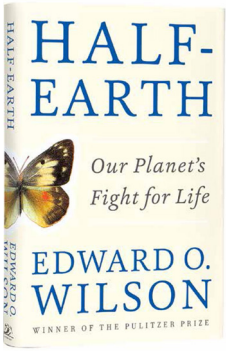
A school of mackerel looking for food. We now live in a TUNA world; Turbulent, Uncertain, Novel and Ambiguous. These conditions challenge us to find models of change that can be scaled up to both help protect the world's biodiversity and produce enough food for a growing population.

PHOTO SOURCE: GETTY IMAGES

Whatever this TUNA-like world throws at us, regenerating the world's bio-diversity and generating higher levels of diversity in our food system will be essential.

Already, many are taking up the challenge. All over the world, dedicated people are creating models of change they believe can be scaled up to both

help protect the world's biodiversity and produce enough food for a growing population. Some of these efforts take place at the macro level and represent sweeping attempts to reimagine what agriculture can be; others are intensely local.



Radical thinking: Wilson envisions a solution that ensures that half of the surface of the land and sea is dedicated to flora and fauna, the equivalent of World Heritage sites for biodiversity.

One of the most ambitious suggestions comes from conservation biologist E.O. Wilson. In his 2016 book *Half Earth: Our Planet's Fight for Life*, Wilson proposes a solution whose very enormity is an indication of the problem's scale: he suggests protecting half the planet by preserving it, undisturbed by humans. *"We now have enough measurements of extinction rates and the likely rate in the future to know that it is approaching a thousand times the baseline of what existed before humanity came along,"* Wilson told *The New York Times* in an interview four years ago. His idea is now being taken increasingly seriously, not only as a way to protect biodiversity but also as a weapon against global warming.

Wilson's plan is not about compartmentalising the Earth or separating one hemisphere for humans and leaving the other for all other living things. Rather, he envisions a solution that ensures that half of the surface of the land and sea is dedicated to flora and fauna, the equivalent of World Heritage sites for biodiversity. The 'half' of the world to be preserved would include places where nature's last remaining habitats remain intact, including parts of the Amazon, New Guinea and the Congo Basin. In Wilson's vision, in the industrialised world, 'corridors' of wild nature would also be restored to allow levels of biodiversity to improve.

The sheer scale of Wilson's approach might leave us feeling powerless in the face of the biodiversity crisis which affects us all, but we shouldn't feel that way. Because change is possible on a smaller scale as well.

It's evident, for example, in the new generation of crop research taking place around the world. Plant breeders are seeking essential genetic traits for the future of our food in crops' wild relatives – the ancient ancestors of the food we depend on today that still grow in the places where they originated. For instance, in southern Mexico, breeders are looking to teosinte, the weedy grass relative which all corn can be traced back to. The Crop Wild Relative project, funded by the British government, is working with wheat's oldest ancestors, such as the wild grasses you might find in the Fertile Crescent, and crossing them with varieties of emmer (an ancient kind of wheat). Scientists working with the project are delving into the plant's history to try and recover some of the 'phenotypic plasticity' that modern wheats have lost but which the plant's wild ancestors still retain; the hope is to find lost DNA that improves the plant's resilience and adaptability.

At the Millennium Seed Bank in southern England, overseen by the Royal Botanic Gardens Kew, botanists have been collecting crop wild relatives from around the world in an attempt to preserve them before they are lost. Someti-

mes, the plant collectors have been too late, as was the case when they arrived in Laos to collect wild rice that had been growing on the fringes of paddies for thousands of years. *"When we got there to collect samples, it had all gone,"* said Chris Cockel, who oversees the Millennium Seed Bank. *"The farmers had been told to clear them away. We're in the 11th hour for saving much of the world's biodiversity."*

Still, there are many examples of individuals and groups all over the world working to restore what has been lost:

"In regenerative agriculture projects, pesticides have been exchanged for a system of natural pest and disease management in which naturally resistant crop varieties flourish."

Seed collector Debal Deb is a saviour of rice diversity in India, proving that you don't need to have much to achieve a great deal. On his two-acre plot of land in Odisha, in the east of India, he is working to help save his country's rice diversity, growing nearly 1,500 different varieties. Many have been collected from remote farms, seeds passed down through generations. Some of these landraces have qualities we may need to call upon in the future, including a variety that is flood-tolerant, capable of surviving after being submerged for weeks. *"It's as if they hold their breath,"* he says, *"and when the water subsides, they start to breathe again."*

Alex Atala is Brazil's most celebrated chef and a pioneer in raising the profile of ingredients used by Brazil's indigenous communities. His ATA Foundation runs eight projects designed to help different indigenous groups survive by making use of their own culture and traditions. One of them works with the Kalunga people who live along the Cerrado river and who collect the wild vanilla – larger and more intensely flavoured than all other known types of vanilla – that grows there. As a spice, vanilla is second only to saffron in price – on international markets, it trades for $500 a kilo. By training Kalunga men and women to pollinate the wild vanilla plants, Atala has improved their harvesting and processing techniques, and their livelihoods. *"One family can make $50 a day [by doing this],"* he says, *"far more money than any welfare payment or what the men can get by becoming involved in illegal mining."* It makes sense to protect the people who protect diversity, he argues.

On tens of thousands of hectares of land in Ribeirão Preto, 350km north-west of São Paulo, Leontino Balbo, the sustainable sugarman, has been proving that regenerative agriculture can be practised on an impressive scale. His business, Native, produces 34 per cent of the world's organic sugar (75,000 tonnes annually). On land where farmers once depended on chemical fertilisers, Balbo has introduced an organic system he has devised himself. Pesticides have been exchanged for a system of natural pest and disease management in which naturally resistant crop varieties flourish.

Based in Mexico City, young couple Francisco Musi and Sofia Casarin have founded Tamoa, a company that makes traditional tortillas using Mexican maize varieties. In doing this, they are working to protect Mexican land-

races, many of which are disappearing, pushed out by imported American corn. Tamoa sources heirloom maize from small farms, paying a fair price directly to the producers who no longer have to leave their communities in search of other work (which is when landrace corns, passed through generations, are lost forever). The company sells dried corn and masa dough (for making tortillas) to restaurants in Mexico City.

The word 'biodiversity' has only recently gained currency because humans are in the process of destroying what it refers to. But as the work of all these organizations – to say nothing of countless scientists, thinkers, and activists – reminds us, this moment of crisis also represents an opportunity to galvanize actions and ideas that will heal the planet and protect the generations to come.

Regenerating the world's biodiversity and fostering higher levels of diversity in our food system is essential for security and resilience – and ultimately for our survival.

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THE
CURT BERGFORS
FOOD
PLANET
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The Curt Bergfors Food Planet Prize aims to identify and reward initiatives and projects that can contribute to reshaping the food system all around the world.

Two prizes of $ 1 million each will be awarded annually, starting in 2020. One prize will go to an existing solution that can be scaled quickly for a global impact. The second prize will go to a radically innovative project that can sustainably transform parts of the food system. The nomination process is currently open.

The Curt Bergfors Foundation was founded in 2019 to support the transition to resilient food systems that protect both people and the environment.

To ensure free and independent research in the field, the foundation is funding a new professorship at the Stockholm Resilience Centre, Stockholm University: *"The Curt Bergfors professorship in sustainability science with a focus on sustainable food systems."* The funding over ten years corresponds to a donation of SEK 20 million.

The foundation is capitalized with half a billion SEK from Curt Bergfors' private assets. It will continuously take new initiatives to contribute to resilient food sourcing and a responsible food culture.

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