

SIR JOHN CRAWFORD MEMORIAL ADDRESS

Building resilience of the biosphere in an interdependent patchwork Earth through diverse food systems

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ABSTRACT



Human actions are profoundly transforming the biosphere upon which humanity depends. While many of these changes have led to significant improvements in human well-being, they have also created a new risk landscape that threatens to undermine the well-being of current and future generations. At the heart of the interaction between people and the biosphere are our food systems. My talk focuses on the changes needed from fork to farm, to build resilience for long-term human prosperity in the Anthropocene – the era of human dominance over the planet. Drawing on my work with the EAT-Lancet Commission on healthy diets within planetary boundaries, I emphasise the necessity of coming together on a global scale to agree on science-based targets for food systems that integrate health, sustainability, and justice ('resilience of what'). These targets must be general enough to apply globally, yet flexible enough to accommodate diverse local contexts. Achieving these targets in an era of unprecedented turbulence will require an improved capacity of all actors in food systems to deal with complex systems and a deeper understanding of how our risk landscape is evolving in this complex interconnected world ('resilience to what'). Creating healthy, sustainable and just food system futures will demand significant shifts in how humans live within, and interact with, the biosphere and each other. Envisioning desirable futures that help us reach global targets is a crucial step toward creating such futures. However, we must recognise the diverse patchwork of local and regional contexts worldwide, each with different value priorities. Any global sustainability transition will emerge from the interactions among geographically variable, but interconnected, pathways of change. Drawing on my interactions with chefs, farmers, innovators, and investors I highlight why recognising this plurality of approaches is crucial for building resilience. Diversity, especially response diversity, is at the core of resilience-building. Ultimately, building resilience is about stimulating the imagination of what a good food system in the Anthropocene can be, and nurturing the diverse pathways that can lead us to this future in a world that consists of a patchwork of solutions. I also emphasise the role of learning and experimentation in navigating this world of fundamental uncertainty and why transdisciplinary science, with strategic partnerships among academia, public agencies, private corporations, and civil society, is vital for resilience-building. I build on lessons learned from the Stockholm Resilience Centre initiatives, such as bringing together academics and CEOs of the world's largest seafood companies to foster ocean stewardship.

Good evening everyone. This address is about the role of the food system in building resilience of our interdependent patchwork Earth, and I hope at the end of it you may know the difference between resistance and resilience.

For me, this feels like a 'full circle' moment. Even though I grew up in Sweden and have spent most of my time in northern Europe, it was actually here in Australia almost 35 years ago that I decided that I wanted to dedicate my life to understanding of how nature supports human well-being, and to use that understanding to help people thrive through the management of ecosystems.

In the year 1990 I was an exchange student in Far North Queensland, on the edge of the Atherton Tablelands. I went to high school in a small village called Ravenshoe, surrounded by stunning unique Australian ecological diversity (such as in the photo here). This was at the time, as many of you already know, a region that had just seen intense conflicts between environmental conservation and timber workers, as the area had recently been declared a World Heritage Site. I found myself in the middle of tensions between the use, the abuse and the



conservation of nature, and it was here that I really started to understand the critical interdependence of people and nature, and the importance of balancing conservation for the sustainable use of natural resources.

Risks to the biosphere

I think everyone in this room is really lucky to be able to experience life for a short period of time in the history of this planet, which is 4.6 billion years old. Yet in such a short time, i.e. in the life span of a generation, there has been so much fundamental change in the biosphere, the thin layer of life that surrounds the planet.

We often talk about the Great Acceleration of human impact, which has taken us into the era of the Anthropocene, the time of human dominance on this planet, during which we have reshaped the biosphere. Today, the weight of plastics on this planet equals the weight of animals on the planet. If you take all the human-made materials on the planet, it weighs as much as the biomass on the planet. These human-made materials are increasing exponentially.

The year 1990, when I was in far north Queensland, is almost halfway between the start of the Great Acceleration (in the 1950s) and where we are today, and the world had just started to come together on environmental issues. The year 1990 was two years after the Montreal Protocol on reducing impacts on the ozone layer. It was the first year that the Intergovernmental Panel on Climate Change (IPCC) published a report on climate change, and it was two years before the Rio conference, where the world came together to establish three new conventions – on climate, on biodiversity and on desertification. While we have seen great and significant progress since 1990, we also know that we are very far from achieving what we need to do. As the IPCC stated, with very high confidence, in its latest report (IPCC 2023): ‘There is a rapidly closing window of opportunity to secure a liveable and sustainable future for all’. Now, more than ever, we need collective action at a global scale.

Resilience and planetary boundaries

I think we all know the huge risks that humanity is facing on this planet right now. We have really changed the whole risk landscape that we are dealing with. We have climate crises and ecological degradation, pandemics and increasing geopolitical tensions. Many of these things are aggravated through the loss of resilience of our biosphere. For example, consider the loss of forest, and the importance of forests in mitigating climate change and even reducing water scarcity.

The way I and my colleagues at Stockholm Resilience Centre use ‘resilience’ is to mean the capacity to keep developing in ways that support human well-being, even in the face of crises. The understanding of resilience of interdependent social or ecological systems is rooted in complex adaptive systems, and it highlights the non-linear behaviour of ecosystems, or any type of system. Complex systems such as ecosystems or societies can

undergo so-called ‘regime shifts’. A regime shift is often seen as a relatively sudden, long-lasting change in how a system functions, in which there is a hysteretic behaviour, which means that it is relatively easy for the shift to happen and it is much more difficult to get the system back to where it was before after the shift. One example of a regime shift is a freshwater lake that can absorb a certain amount of nutrients without any obvious impact. But once pollution levels cross a threshold, there can be a tipping point, and the lake suddenly shifts from a clear-water lake sustaining fisheries to an algae-dominated state with insufficient oxygen for fish life. When the system is close to such a tipping point, even a small disturbance, such as climate fluctuation or a big storm, can tip the system into a new regime.

Loss of resilience is often invisible to us before the system tips and we end up in a state where we did not want to be. These kinds of tipping points are found in most ecosystems. We see them in coral reefs: from beautiful reefs with lots of fish life to algae-dominated or bleached areas. We see them in rainforests tipping to more savanna-like systems; grasslands changing to more deep-rooted vegetation with less capacity to support livestock. We can also see this type of tippings in society. One can think about trust as a good example. Trust takes a long time to build up, but it is very easily lost.

At the Stockholm Resilience Centre, we study resilience on scales ranging from local to global. As we move from being a small world on a big planet to a big world on a small planet, we are adjusting the resilience of the Earth system as such, and we now know that there are risks of tipping points at the Earth system scale.

In 2009, the first paper on planetary boundaries was published, led by Professor Johan Rockström, who was a co-founder of the Stockholm Resilience Centre, and Professor Will Steffen of the Australian National University here in Canberra. They brought together a group of scientists who identified thresholds of the safe operating space on this planet: that is, the boundary between the space where humanity can thrive, and where it risks destabilising the self-regulating processes on this Earth in ways that potentially unleash changes that would put humanity at risk.

Planetary boundaries are people-centric. Defining them is about ensuring that the planet remains in a state that can support and be liveable for future human generations. It also takes a systemic approach, by considering not just climate but nine different variables that are relevant to how the Earth system operates: biodiversity, land use, biogeochemical cycles, water, etc. (Figure 1).

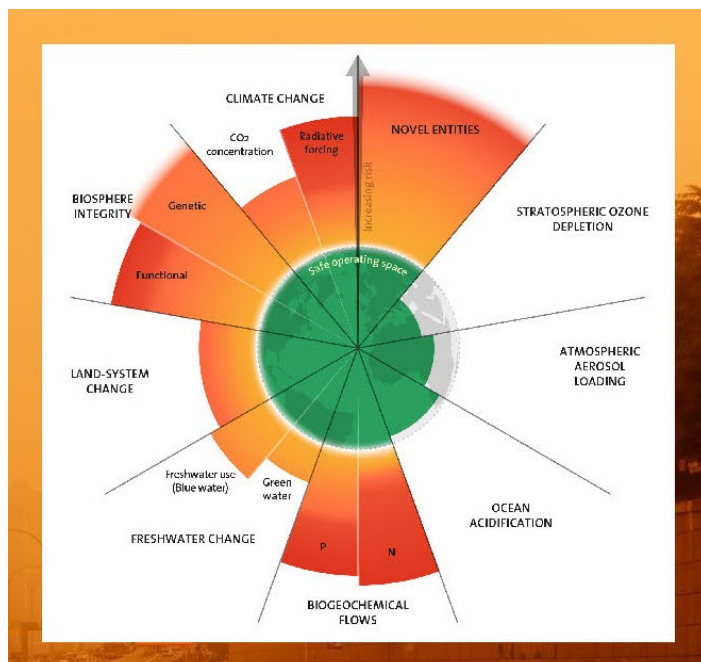


Figure 1. Planetary boundaries: we are transgressing the safe operating space for humanity.

So how are we doing? Well, not that great. In 2009, out of nine boundaries, six of them had been assessed and we had crossed four of them. They all have been assessed now. The latest assessment published last year shows that now we have crossed six of the nine boundaries.

Food and the Planetary Health Diet

Food production lies at the heart of the pressures on the planetary boundaries. It contributes up to 30% of the impacts on climate; around 70% of the pressures on water resources; around 75–80% of the pressures on biodiversity and land use change; and about 100% of the pressures on nitrogen and phosphorus. We also know that poor diets are a major global health risk, with 2 billion people being obese and 735 million undernourished – numbers that we know have been growing rapidly over the past few years.

We have, since the 1990s, global conventions and targets for many of the aspects that I have mentioned, but we do not have a target for a healthy diet that it would be possible to produce within the planetary boundaries. But what if we could come up with something that is globally relevant and agreeable, and that considers both the health of people and the planet? Would it then be possible to feed the 10 billion people that are expected to be living on this planet by 2050?

Eight years ago, we started to work on the first EAT-Lancet Commission on food in the Anthropocene. The Commission was set up by the EAT Foundation, whose mission is to unite health and sustainability through food systems across science, policy and business. The Secretariat for the Commission was based at the Stockholm Resilience Centre.

We gathered a group of nearly 40 scientists, including nutritionists, agronomists, sustainability scientists and others that worked on these questions for over three years. The EAT-Lancet Commission was published in 2019, and it introduced the concept of a Planetary Health Diet outlining healthy ranges for food group intakes. The Planetary Health Diet is designed for human health. It is a plan for a diet with ample room for whole grains, fruits, vegetables, nuts, pulses, but also some room for red and white meat, eggs, seafood and dairy. Figure 2 is an example of one day's intake of the Planetary Health Diet.

The results showed that if we just shifted to this diet, everyone globally would be healthier and it would also ease pressure on the climate boundary. However, it is not enough to let us stay within the other environmental boundaries. In order to also reduce the pressures across all of the boundaries, we need substantial and transformative change also in agriculture, especially closing the yield gaps in low-income countries and reducing the pressure on the environment in high-income countries. We also need to halve food loss and waste. If we do those things, we could, basically, eat and produce a healthy diet within planetary boundaries.

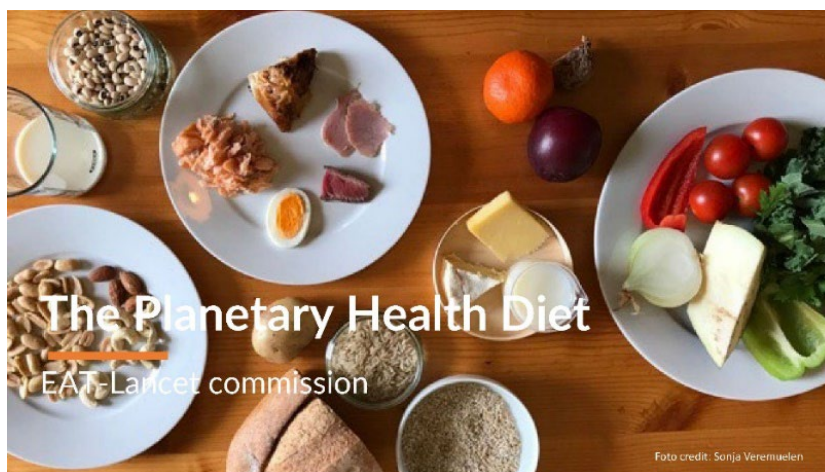


Figure 2.

When the scientific journal *Nature* recently looked at the ten most cited non-economic papers in policy documents of all times, the EAT-Lancet report was one of them, along with two of the initial planetary boundary papers. These global frameworks are being used by companies, countries, governments, public authorities and civil society around the world to develop guidelines and assess progress towards sustainability and health targets.

However, one of the main criticisms of the EAT-Lancet report was that the Planetary Health Diet was seen as a one-size-fits-all global diet, implying that everyone would be eating basically the same thing. That was a misconception. The planetary diet allows for plenty of different adaptations (Figure 3).



Figure 3. A healthy diet can be eaten in a diversity of ways.

Right now, we are working on an update of the EAT-Lancet diet, and there is also an effort led by Professor Wen-Harn Pan from Taiwan, in collaboration with scholars worldwide, to create a two-day meal plan that can be tailored to different parts of the world. This project highlights how the Planetary Health Diet can be adapted for different contexts.

Changing people's diets

We have been working on a two-day meal plan for Sweden. Currently, the Swedish per capita consumption exceeds our 'fair share' of the planetary boundaries by up to four times in all areas except water use. This is largely due to the high meat and dairy consumption in Sweden, which has doubled since the 1990s.

So how do we create a meal plan that is rooted in Swedish culture, that people recognise and could aspire to, but yet is transformative enough to bring us within our fair share of the planetary boundaries?

We have been working with an experimental farm, and a philanthropic organisation called Axfoundation to explore the most popular Swedish dishes. We have adapted them to be more future oriented and in line with the Planetary Health Diet. For example, one of the most Googled recipes in Sweden is Pasta Bolognese! So we have taken Pasta Bolognese as one of the main dishes on this two-day meal plan but we have exchanged the minced meat for minced pulses (legumes), using four different pulses, and we are working with some of the best chefs in Sweden to ensure that we also get the taste right. We also looked at fish stew, which is another very popular dish in Sweden. We exchange some of the fish most commonly used for the fish stew (such as salmon), for mussels and clams and fish that are being grown from larvae fed on food waste.

One thing that has struck me when I have worked on Swedish diets is the enormous number of snacks that we eat in Sweden. 'Fika' is central to Swedish culture (Figure 4). It is a tradition that involves taking a break with coffee and something sweet. The key element of fika is not really the coffee or the treat but rather the time spent connecting with others. It is basically a social-care institution.

Obviously fika is not healthy, nor sustainable. Many of the products grown for fika have decreasing supply and increasing demand globally. We are now looking at how we can adapt fika to be more in line with the

challenges of the Anthropocene, because we really want to maintain this institution and way of eating but we also need to see a change.

We have learned in this work that we need to pay more attention to the role of intermediate meals. We should also focus more on the role of food as being more than just nutrition, and we should explore whether leading with ‘culture’ in our messaging around food system transformation could help drive the change that we need to see.



Figure 4.

That day in January of 1990 when I met my Australian host family for the first time is still so strong in my memory. I was completely exhausted after not sleeping on the long flights, and I found myself sitting in a very noisy pickup truck with my new host father speaking in a very deep Australian accent, and I just could not understand anything.

When we finally arrived at the house, the first thing we did was to head to the kitchen. They offered me a mango. It was cut in a way that I had never seen before, and I can still remember that feeling of the juice running down my fingers as I leant over the kitchen sink to eat it. In Sweden I had had mangoes before, but just in tiny pieces. My parents worked for Thai Airways and they sometimes brought home a mango. We would split it between the four of us in the family and we would each get a small piece of mango. And here I was, suddenly slurping one all down by myself – a whole mango! I felt an overwhelming sense of gratitude and calmness, and I realised ‘I can do this year of exchange!’.

Just as with the example of fika, food can be so much more than merely the energy and the nutrition that it provides. Food is culture. It is an expression of generosity, compassion, community and flavour. It is something that really binds us together.

Since 1990, mango imports to Sweden have increased by a factor of more than 15. This reflects a broader trend of increased global food trade. Trade has significantly enhanced food security and has the potential to produce more food with less environmental impact. It is fascinating to see that trade has increased the diversity of food available in every single location around the world, but globally we are eating more and more in the same way.

Diversity for food security

Essentially, we eat more diverse food but in an increasingly similar way. The global food system is homogenising and simplifying, with overall fewer species and genetic varieties being used. Today, nearly 50% of the calories that we consume are based on just three species – wheat, maize and corn – and somewhere between 40 and 75% of the production volumes come from only six ‘bread baskets’ around the world. With Russia’s invasion of Ukraine, there is currently war in one of these bread baskets. We know that the risk of synchronous droughts happening across multiple bread baskets at the same time has massively increased with climate change. We also see a simplification of the transport system around the world, with several marine chokepoints making us vulnerable to food supply transportation. Just think of the Evergreen company’s container ship being stuck in

the Suez Canal; and political tensions in the Red Sea; or drought limiting passage through the Panama Canal. For far too long we have focused too much on optimisation and efficiency.

As we enter an era of unprecedented turbulence on this planet, we need to shift our focus towards building diversity of solutions. A fundamental concept in resilience thinking is ‘response diversity’. This idea comes from ecology and refers to the variety of responses to environmental changes. Most species perform similar functions. A high response diversity ensures that if some species are negatively impacted by a disturbance like climate change, others can compensate and maintain the ecosystem function and stability. In many ecosystems, species that may seem redundant in the current operation actually ensure that system can function also in disturbances, because of the diversity of responses and built-in redundancy. They reduce risks associated with any single strategy failing. In a world that not only needs stability but also demands new ways of action, building resilience through response diversity is about sparking imagination and envisioning what a good food system in the Anthropocene could look like, and nurturing a diversity of pathways to lead us there.

In this context, I would like to highlight a project called [Seeds of Good Anthropocenes](#). It is a Future Earth initiated project led by Stockholm Resilience Centre, McGill and Stellenbosch universities. At the heart of this project is the idea that most of the visions of the future that we see today are dystopian and merely extensions of our current world. The Seeds of Good Anthropocenes project collects inspirational examples of alternative futures that are already happening but are on the margins today. These examples are then analysed to understand how and why they work, and how they could be nurtured to grow into new positive futures.

The ‘seeds’ represent a diverse mix of disciplines, worldviews and values. There are over 500 examples now in our database. Figure 5 shows examples: urban rivers resurfacing in Korea; Svalbard Global Seed Vault; an indigenous example, the Gwaii Haanas Tribal Park in British Columbia, Canada; rewilding of Scottish rainforest; and the Foundation for Ecological Security in India. The scientists behind the Seeds of Good Anthropocenes project are now bringing together stakeholders from these various cases to build positive and plausible scenarios, in different regions around the world.



Figure 5.

I asked one of the leaders of this project about the insights gained so far, and they said they have learnt three lessons.

- First, you need to invest in experimentation, and you need to ensure learning is happening. It is crucial to monitor, evaluate and learn from these experiments.
- Second, identify and reduce the barriers for solutions that are now on the margin. We need to ‘level the playing field’ with more conventional approaches: most resources today still go into traditional approaches.

- Third, we need to facilitate networking and collaboration among these different ‘seeds’, enabling them to learn from each other and find potential collaboration. That is vital.

However, the world is not moving towards encouraging a diversity of solutions. Instead, we are becoming more and more homogenous, as I already said. It is not just in terms of species, but also in terms of the actors that are driving our global production ecosystems. A few years ago, I and my colleagues published a paper (Folke *et al.* 2019) which showed how just a few companies are dominating the production chains of many commodities. For instance, five companies now control 90% of the world’s palm oil market; ten companies control 83% of all animal pharmaceuticals; and three companies control 60% of global cocoa production.

Driving transformative change

The research for that paper was inspired by another project at the Stockholm Resilience Centre in 2012. My colleagues asked an intriguing question: Could there be keystone actors within the seafood industry that are capable of driving transformative change towards better ocean futures? A keystone species is a species that is low in abundance but has a really strong impact on the ecosystem. The research uncovered that a small number of companies had a significant influence over the seafood industry: 13 companies were found to control between 20% and 40% of the largest and most valuable fish stocks, as well as 11–16% of the overall global marine catch. This concentration of power represents both a challenge and an opportunity.

On the one hand, it raises questions of legitimacy and agency. On the other hand, what if these keystone actors – defined by their dominance in global production revenues, their control over crucial production segments and their influence over global governance processes – could be mobilised to become stewards of the oceans and drive transformative change? After years of bilateral contacts and lobbying, my colleagues managed to bring eight CEOs of the world’s largest seafood companies together to meet for the first time. They made a shared commitment to ocean stewardship.

This meeting marked the beginning of SeaBOS, a global science business initiative dedicated to driving sustainable practice within the seafood industry. Today, SeaBOS facilitates annual CEO-level dialogues with scientists, across nine companies, bridging the gap between research and industry. The approach is about mutual learning, co-design and sustainable practices. It is about fostering change through collaboration and dialogue. The CEOs have agreed on five timebound goals, including: the reduction of illegal, unreported and unregulated fishing; advancing the protection of biodiversity and ecosystems; combating antimicrobial resistance; building climate resilience; and reducing ocean plastics. In their latest annual reports, all companies have advanced towards the targets (there is one tiny exception).

However, we still regard this as a big experiment. We need to see the results of the hypothesis that it is possible to mobilise these companies. They have come a long way, but there is a much longer journey ahead of them.

As we navigate the complexities of the Anthropocene, it is clear that our food systems are at the heart of both the challenges and the solutions. For resilience, the current direction of a strong focus on simplification and efficiency is one of the problems. Achieving sustainable and resilient food systems demands transformative change, embracing a diversity of solutions, fostering global collaboration and envisioning new pathways for the future.

Our journey toward a more resilient Earth through sustainable food systems requires imagination and commitment from all sectors of society, large and small. By learning from successful examples and committing to collective action, we can build a future where both people and planet can thrive.

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Line Gordon has over 20 years of experience leading interdisciplinary teams in Sustainability Science. Her leadership focuses on investing in a collaborative, trust-based and creative working culture that enables us to achieve impact, while ensuring that scientific integrity underpins all our work. Line Gordon's research focuses on water and food systems as key entry points to build Biosphere resilience and improve governance of social-ecological systems, livelihoods, and public health. Her research is problem-oriented, interdisciplinary, and highly collaborative. She often leads and contributes to collaborations that bridge disciplines and technical skills to advance scientific frontiers. Gordon's current research focuses primarily on the role of food system transformation for public and planetary health. This work includes leading the Just transformation working group of the EAT-Lancet 2.0 Commission, developing national Swedish food systems scenarios in the Mistra Food Futures program, and working on gastronomic landscapes. She has previously done research on livelihood resilience and ecosystem services in sub-Saharan Africa (Burkina Faso, Tanzania, South Africa, Senegal, and Ghana), and on the critical roles of 'invisible water flows' across local to global scales, in particular highlighting how global land use change, and evaporation and precipitation interact. Line Gordon has an undergraduate degree in biology, and a PhD (in 2003) in Natural Resources Management, Department of Systems Ecology, Stockholm University. She was a postdoctoral fellow at the International Water Management Institute (IWMI) in Colombo, Sri Lanka. She has also been a visiting researcher at University of Kwa-Zulu Natal, South Africa, CIRAD in France, McGill University in Canada, and STIAS – the Stellenbosch Institute for Advanced Study in Stellenbosch, South Africa. She was appointed the Curt Bergfors Professor in Sustainability Science with a focus on food systems in 2021. Line Gordon serves on many different boards and advisory boards.